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BROS PHASE 2 RI/FS
WORK PLAN

Bridgeport Rental and Oil Services Site
Logan Township, New Jersey

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BROS Technical Committee

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Acronym And Unit Definitions

Acronyms	Description
ACL	Alternative Concentration Limit
ADQO	Alternate Data Quality Objective
AIC	Acceptable Intake - Chronic
AMSL	Above Mean Sea Level
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirements
ASP	Analytical Services Protocol
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AUF	Area Use Factor
AWTS	Aqueous Wastewater Treatment System
BGS	Below Ground Surface
BOD	Biological Oxygen Demand
BROS	Bridgeport Rental and Oil Services
BTEX	Benzene, Toluene, Ethylbenzene and Total Xylenes
BTU	British Thermal Unit
CDM	Camp, Dresser and McKee
CEA	Classification Exception Area
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Register
CLP	Contract Laboratory Program
CLTL	Chemical Leaman Tank Lines
COD	Chemical Oxygen Demand
COPC	Constituent of Potential Concern
COPEC	Constituent of Potential Ecological Concern
CPF	Cancer Potency Factor
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limit
CRPP	Community Relations Participation Proposal
CRQL	Contract Required Quantitation Limit
CRS	Cultural Resources Survey
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DQO	Data Quality Objective
DRBC	Delaware River Basin Commission
DRO	Diesel Range Organics
DUR	Data Usability Report

Acronym And Unit Definitions

Acronyms	Description
DVS	Data Validation Services
EDI	Estimated Daily Intake
ER-L	NOAA Effects Range - Low
ERA	Ecological Risk Assessment
FDA	Food And Drug Administration
FEMA	Federal Emergency Management Agency
FID	Flame Ionization Detector
FIT	Field Investigation Team
FOP	Field Operations Plan
FS	Feasibility Study
GIS	Geographical Information System
GPS	Global Positioning System
GRO	Gasoline Range Organics
GWQC	Ground Water Quality Criteria
HASCP	Health and Safety/Contingency Plan
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
ICLR	Incremental Lifetime Cancer Risk
IDL	Instrument Detection Limit
IRIS	Integrated Risk Information System
LC50	Lethal Concentration (for 50% of Population)
LD50	Lethal Dose (for 50% of Population)
LEL	Lowest Effect Level
LNAPL	Light Non-Aqueous Phase Liquid
MCL	Maximum Contaminant Limit
N.J.A.C.	New Jersey Administrative Code
NAAQS	National Ambient Air Quality Standards
NAPL	Non-Aqueous Phase Liquid
NCEA	National Center for Exposure Assessment
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NGVD	National Geodetic Vertical Datum
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level

Acronym And Unit Definitions

Acronyms	Description
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethylene
PEL	Permissible Exposure Level
PID	Photoionization Detector
PM_{10}	Particulate Matter Less Than 10 Micron in Aerodynamic Diameter
PPE	Personal Protective Equipment
PQL	Practical Limits of Quantitation
PRAO	Preliminary Remedial Action Objective
PRG	Preliminary Remedial Goal
PRM	Potomac-Raritan-Magothy
PRP	Potentially Responsible Party
PWSC	Pennsgrove Water Supply Company
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RA	Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objectives
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RFD	Reference Dose
RI	Remedial Investigation
RMEI	Reasonable Maximum Exposed Individual
ROD	Record of Decision
ROST	Rapid Optical Screening Tool
SAB	Science Advisory Board
SAP	Sampling And Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SCBA	Self Contained Breathing Apparatus
SCC	Soil Cleanup Criteria
SHSO	Site Health and Safety Officer

Acronym And Unit Definitions

Acronyms	Description
SMDP	Scientific/Management Decision Point
SOP	Standard Operating Procedure
SOW	Scope of Work
SPHEM	Superfund Public Health Evaluation Manual
SPLP	Synthetic Precipitation Leaching Procedure
SQB	Stream Quality Benchmarks
SQL	Sample Quantitation Limit
SQO	Stream Quality Objectives
SSL	Soil Screening Level
SVOC	Semivolatile Organic Compound
TBC	To-Be-Considered
TCE	Trichloroethylene
TCL	Target Compound List
TCLP	Toxic Characteristic Leaching Procedure
TDI	Total Daily Intake
TDS	Total Dissolved Solids
TI	Technical Impracticability
TIC	Tentatively Identified Compound
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOX	Total Organic Halides
TPH	Total Petroleum Hydrocarbon
TSP	Total Suspended Particulate
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
USACOE	United States Army Corps of Engineers
USDC	United States District Court
USEPA	United States Environmental Protection Agency
USGS	United Sates Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WET	Wetland Evaluation Technique

Acronym And Unit Definitions

Units	Description
μg/ℓ	Micrograms per Liter
μg/m^3	Micrograms per Cubic Meter
μg	Micrograms
μg/kg	Micrograms per Kilogram
μg/kg/day	Micrograms per Kilogram per Day
μℓ	Microliters
μ	Microns
cm^2	Square Centimeters
°C	Degrees Centigrade
°F	Degrees Fahrenheit
kg	Kilograms
K_p	Dermal Permeability Coefficient
ℓ/cm^3	Liters per Cubic Centimeter
ℓ/m^3	Liters per Cubic Meter
ℓ/day	Liters per Day
ℓ	Liters
m^3/day	Cubic Meters per Day
m^3/hour	Cubic Meters per Hour
mg/ℓ	Milligrams per Liter
mg	Milligrams
mg/m^3	Milligrams per Cubic Meter
mg/kg-day	Milligrams per Kilogram per Day (Daily Exposure)
mg/cm^2	Milligrams per Square Centimeter
mg/day	Milligrams per Day
mg/kg	Milligrams per Kilogram
mg/kg/day	Milligrams per Kilogram per Day (Average Daily Exposure)
mℓ	Milliliters
mm Hg	Millimeters of Mercury
ppb	Parts per Billion
ppm	Parts per Million

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EXECUTIVE SUMMARY

Introduction

The Bridgeport Rental and Oil Services (BROS) Superfund Site is located on Cedar Swamp Road in Logan Township, Gloucester County, New Jersey. At various times, the current and previous owners and operators used the site for several purposes, including waste oil reprocessing, waste disposal, and waste storage. The United States Environmental Protection Agency (USEPA) placed the site on the National Priorities List on September 8, 1983 (See 48 Fed. Reg. 40, 658) and commenced a Remedial Investigation and Feasibility Study (RI/FS).

The RI/FS identified several sources of contamination and various contaminated areas. On December 31, 1984, USEPA issued a Record of Decision (ROD) which called for: (1) installation of a water supply line to replace private water supplies near the site; (2) dismantling of the tank farm at the site; (3) excavation and on-site incineration of lagoon sediment; and (4) performance of a Phase 2 RI/FS to address ground water at and emanating from the site.

Two major law suits were filed with regard to the BROS site. On March 20, 1992, thirteen private parties filed suit in *Rollins Environmental Services (NJ) Inc., et al. v. United States, et al.* against the United States Department of Defense and certain named departments and agencies (including the Defense Logistics Agency and the Departments of the Army, Air Force, and Navy) and certain private parties. On June 30, 1992, the United States of America, on behalf of USEPA, filed a complaint against a number of corporate defendants in *United States v. Allied Signal, Inc.* The complaint was amended on November 30, 1992 (USDC, 1997a).

The Court consolidated the *Allied Signal* and *Rollins* cases on October 2, 1992. On March 31, 1993, the State of New Jersey, Department of Environmental Protection (NJDEP) intervened in the *Allied Signal* action as a plaintiff. In May 1993, the *Allied Signal* defendants counter-claimed against NJDEP and asserted claims against the New Jersey Department of Military and Veterans Affairs and the New Jersey Department of Transportation.

The *Rollins* and *Allied Signal* cases were essentially resolved by a Consent Decree entered by the Court on January 17, 1997 (USDC, 1997a). Under that Consent Decree, which provided for financial contributions to the ongoing BROS cleanup from federal, state, and private PRPs; the Settling Defendants, including a number of private parties allowed by the Court to intervene as defendants in the *Allied Signal* action for the purpose of participating in the Consent Decree, assumed responsibility for implementation of the Phase 2 RI/FS activities intended to identify remedial actions for ground water and wetlands.

The BROS Technical Committee, composed of senior managers employed by certain Settling Defendants, selected Environmental Liability Management, Inc. as the Project Coordinator and Roux Associates, Inc. as the contractor to develop and implement the Phase 2 RI/FS activities. These activities are outlined in the Statement of Work in the Consent Decree and detailed in this Work Plan and its associated documents. The information generated and compiled during the Phase 2 RI/FS, including public participation, will be used to select the remedial action or actions for ground water and wetlands. These remedial actions may include actions to address the residual contamination in the soils at the BROS property and final closure of the incinerator ash management unit. USEPA will describe the scope of these actions and how they were selected in a Phase 2 Record of Decision (ROD).

Overview of Phase 2 RI/FS Work Plan

The purpose of the Phase 2 Remedial Investigation/Feasibility Study (RI/FS) Work Plan is to describe the tasks and supporting rationale for the proposed assessment of site conditions and evaluation of alternatives to the extent necessary to select a remedy for the BROS Superfund site. Consistent with the Statement of Work in the Consent Decree, the Work Plan is based upon evaluations conducted during the scoping process, including a review of available data from prior investigations and remedial actions at the site. In addition, in the preparation of the Work Plan Roux Associates, Inc. relied on the National Contingency Plan (NCP, 1990), the New Jersey *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E), and the USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a). Other documents were concurrently developed and are cross-referenced in the Work Plan including the Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan (SAP) and Health and Safety Contingency Plan (HASCP).

The Phase 2 RI study will collect the data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives, building upon the previously conducted studies and remedial actions. In addition, the Phase 2 RI site characterization will provide the information necessary for the completion of a site-specific baseline risk assessment which will evaluate the current and potential threats to human health and the environment that may be posed by residual contaminants in ground water, surface water, air, soil, sediment or potentially bioaccumulating in the food chain. The risk assessment will be used to support the development, evaluation, and selection of appropriate response alternatives in the Phase 2 FS (USEPA, 1998f).

The primary objective of the Phase 2 FS will be to ensure that appropriate remedial alternatives are developed and evaluated so that relevant information concerning the remedial action options

can be presented to a decision-maker and an appropriate remedy can be selected. Development of the alternatives will be fully integrated with the site characterization activities of the Phase 2 RI. Alternatives will be developed to protect human health and the environment by eliminating, reducing, and/or controlling risks arising from each pathway associated with the entire site as well as risks arising from specific areas of concern or hot spots.

Site History

The BROS site is located on Cedar Swamp Road between US Route 130 and Interstate 295 (Figure 1). This site includes a 30-acre facility formerly used (First by Regal Petroleum and then by Bridgeport Rental and Oil Services) for waste oil reprocessing, waste disposal, and waste storage and now known as the BROS property. All industrial operations associated with waste oil have been shut down and the equipment removed. In addition to the BROS property, the BROS site is defined in the 1997 Consent Decree to include all areas adjacent to the BROS property where contamination exists as a result of the past operations.

Prior to the initiation of waste oil operations, the BROS property was an upland farm area that was subsequently used for a sand mining operation with the excavation extending below the water table. A 13-acre pond remained on the property when the upland portion of the BROS property was developed into a waste oil operation around 1960. During the period of waste oil operations, between 1960 and the early 1980s, industrial operations occurred primarily in three areas: the waste oil processing and storage tank area, a building known as the Pepper Building, and the 13-acre pond which became a waste oil lagoon (Figure 2). The operations resulted in oil-based and aqueous based contamination of soils and ground water. In 1972, following heavy rains associated with a hurricane, the lagoon overflowed into the adjacent Little Timber Creek Swamp. Interim lagoon stabilization actions were taken during the 1970s. The USEPA initiated a series of response actions in 1981 and began remedial actions following the signing of the 1984 ROD.

Since the issuance of the 1984 ROD, the following remedial actions have been completed:

- installation of potable water lines in the vicinity of those known residences whose supply wells could potentially contain site-related constituents;
- demolition and removal of the tanks, process vessels and underground piping;
- on-site incineration of oil, sludge, sediment and soil from the former lagoon;
- on-site treatment and discharge of 190 million gallons of ground water pumped from the lagoon during the incineration work;

- removal of sediment from a limited area in the adjacent wetlands, east of the former tank storage area and near US Route 130;
- on-site disposal of the incineration ash in the former lagoon area; and
- off-site disposal of debris and other materials which could not be incinerated on-site.

Current BROS Property Condition

Currently, the former lagoon area and the former waste oil processing and tank storage area are grass covered. The areas have been backfilled with off-site soils and incinerator ash from the on site lagoon incineration activities. Soils from off-site were also used to cover the ash layer prior to seeding. The Pepper Building remains in essentially the same condition that it was in at the time of the 1984 ROD. Two office trailers, utilized by USEPA during incineration activities, remain on the BROS property for use during the Phase 2 RI/FS. In addition, the former waste water treatment plant, constructed by USEPA's contractor and utilized during both the tank farm demolition activities and the on-site incineration project, remains on the BROS property in a decommissioned condition. The BROS property is surrounded by a fence.

Environmental Setting and Quality

The USEPA conducted preliminary remedial investigation activities to assess the quality of soils, ground water, and wetlands at the site. Data from these investigation activities are summarized in a report compiled by the USEPA's contractor (CH_2M Hill, 1996). This Work Plan was developed, in part, utilizing those data as well as other sources of site information, including data from the US Army Corps of Engineers on the lagoon work, data and observations from the recent soil sampling work conducted on the BROS property by a USEPA contractor, and information from similar investigations conducted at the nearby Chemical Leaman Tank Lines Superfund Site. All of the sources of information were used in this Executive Summary and the Work Plan, unless noted otherwise.

The BROS site lies within the Atlantic Coastal Plain physiographic province which is characterized by relatively flat topography, low gradient streams, and a series of alternating sand and clay dominated subsurface formations overlying bedrock. A thin surface strata of recent alluvium covers the Upper Potomac-Raritan-Magothy Formation (Upper PRM) which is under water table conditions near the surface. Recent fill material, alluvium, and peat layers associated with current and past wetland areas are mixed on the BROS property. The thickness of the Upper PRM ranges from 10 to 80 feet beneath the site. Soil contamination, primarily petroleum hydrocarbons, lead, and volatile organic compounds (VOCs) has been detected in subsurface soils

beneath the BROS property. Based on the limited data the distribution of site-related constituents in soil beyond the BROS property appears limited to the immediate vicinity of the property

Petroleum hydrocarbons in the form of light non-aqueous phase liquids (LNAPL) have been reported in several locations throughout the BROS property, including: near the southwest side of the Pepper Building, beneath the former lagoon, around the perimeter of the former lagoon, and in the former tank storage area. Recent soil borings reportedly detected LNAPL several feet below the current water table at several locations on the BROS property. Some ground water monitoring wells contain measurable quantities of LNAPL. In close proximity to the BROS property, LNAPL residuals have been reported in two locations: on the water table below the swale along U.S. Route 130 and in sediment in the Little Timber Creek Swamp. The distribution, characteristics, and composition of LNAPL in soils at or in close proximity to the site are not known in adequate detail. In wetland sediments, the distribution of residual LNAPL appears to be related to the distribution of emergent herbaceous vegetation (*Phragmites*) in the otherwise swamp habitat, dominated by red maple overstory trees.

Sediment and surface water contamination has been detected in Gaventa Pond near a former seep from the former waste oil lagoon and in Little Timber Creek Swamp as a result of the 1972 lagoon overflow. The principal site-related constituents for these areas include petroleum hydrocarbons, lead and PCBs. Metals were also detected in one sediment sample collected from Swindell Pond at concentrations in excess of screening criteria. In Swindell Pond, no VOCs, SVOCs or PCBs were detected in sediments at concentrations exceeding the screening criteria and contamination was not detected in surface water. Limited additional delineation is needed in Gaventa and Swindell Ponds, but significant additional evaluation of the distribution and characteristics of contaminants in surface water and sediment is necessary in Little Timber Creek Swamp, including the area between U.S. Route 130 and Cedar Swamp Road.

Ground water flow in the Upper PRM is driven by local topography and surface water-ground water interaction. Currently, the ground water flow pattern in the Recent strata and the Upper PRM at the BROS property is not known with any certainty because the hydrology has been modified by remedial activities and no data have been collected since the cessation of the lagoon dewatering activities and the back filling of the former lagoon. Historically, the liquid in the lagoon was a mound in relation to adjacent ground water. The lagoon area then became a ground water depression point for a number of years as a result of lagoon remedial activities which included dewatering of soils by lowering the water table. The distribution of site-related contamination, primarily volatile organic compounds, in the Upper PRM appears limited to the BROS property and its close proximity. However, the distribution and concentrations of site-

constituents is not known beneath the Little Timber Creek Swamp adjacent to the BROS property. In addition, the influence of several years of lagoon excavation and ground water withdrawal on the ground water quality in the Upper PRM is not known because sampling has not been conducted since 1993 and the lagoon remedial activities, including dewatering, continued until the end of 1996.

Beneath the Upper PRM is a confining layer which may be discontinuous beneath a portion of the former waste oil lagoon based on its reported absence at one location along the southeast side of the former lagoon. Elsewhere throughout the site, the confining layer has been clearly documented and is approximately 15 feet thick. If the confining clay is absent beneath a portion of the lagoon, which has not been confirmed, the gap in the confining layer may have provided a pathway for the movement of ground water contaminants downward into the Upper Middle PRM. This might have been possible especially during the period when water was mounded in the lagoon or when lagoon dewatering was suspended during incinerator down times, allowing ground water elevations to recover in the excavation. However, no stratigraphic information is available from beneath the former 13-acre lagoon, and no soil samples have been collected from the confining layer and analyzed for site-related constituents.

Beneath the upper confining layer is the Upper Middle PRM, a semi-confined aquifer that ranges in thickness from 40 to 90 feet. In the early 1990's, the vertical direction of ground water flow was upward, except at one location. Ground water contamination consists primarily of volatile organic compounds which are distributed in the Upper Middle PRM along the direction of ground water flow to the southeast, in the vicinity of Interstate Route 295 (Figure 12). Concentrations decrease substantially with distance from the former lagoon. Drinking water standards along Interstate Route 295 are exceeded minimally for only two constituents. Further southeast and downgradient along Swedesboro-Paulsboro Road, there have been no site-related contaminants detected above ground water standards. The reported detection of two potentially site-related constituents in one well has not been confirmed. Consequently, the downgradient distribution of site-related constituents is not clearly established.

The Lower Middle PRM underlies the Upper Middle PRM and is separated by a continuous clay layer which ranges in thickness from 8 to 20 feet beneath the BROS site (CH_2M Hill, 1996a). Some low concentrations (less than 10 ppb) of VOCs were detected in some wells in the Lower Middle PRM near the former lagoon, but they may be the result of carrydown from the Upper Middle PRM during drilling or as a result of movement along the casing of the well. No further assessment of the Lower Middle PRM is proposed due to the low concentrations detected (CH_2M Hill, 1996a) and the subsequent removal of the primary source (the former lagoon).

Specific Phase 2 RI/FS Objectives and Data Needs

The specific Phase 2 RI/FS objectives are a function of the data needs which were identified and refined during the Work Plan scoping process. The new data and additional information collected during the Phase 2 RI/FS will be used to complete the compilation of the relevant information needed for the selection of remedial options. The remainder of this section summarizes the Phase 2 RI/FS objectives and data needs which have been integrated into the scope of work presented in the Work Plan.

Objective 1 - Establish a Water Budget for the Site

Data and Technical Evaluation Needs:

- Establish the direction and magnitude of water movement through various environmental compartments at the site, especially the discharge/recharge relationship between ground water and surface water.

- Understand the fluctuations in flow and discharge/recharge relationships caused by seasonal changes and precipitation events.

- Determine the relative potential for contaminant movement through aqueous pathways; soil leaching, incinerator ash/lime leaching, ground water movement, and surface water transport.

- Evaluate the effects of various potential remedial alternatives (i.e., capping, pumping and treatment, engineering containment) on the movement of water and associated contaminants as well as on the hydrology of the adjacent wetlands.

The water budget analysis, linked with other sampling and evaluation activities, will satisfy the data needs identified above. Based on the water budget evaluation results, the conceptual site model will be refined and provide the template for the fate and transport assessment which will be used in human health risk assessment, ecological risk assessment, and the Phase 2 FS.

Objective 2 - Establish the Spatial Distribution, Volume and Mass of Contaminants Associated with Residual Source Areas

Data and Technical Evaluation Needs:

- Determine the vertical and horizontal distribution of free product; defined as the LNAPL that would flow into a well or other recovery point.

- Evaluate the recoverability of the free product (LNAPL).

- Determine the vertical and horizontal distribution of residual product; defined as the LNAPL that remains in the soil pore space but will not flow into a well or other recovery point.

- Characterize the constituents of the LNAPL at various locations on the BROS property and in the adjacent wetlands.

- Estimate the mass of LNAPL above and below the current water table.

- Determine the relative mobility potential of the constituents of the LNAPL.

- Understand the physical (e.g., viscosity, BTU value) and chemical characteristics of the LNAPL in the former Process and Tank Areas and lagoon residuals below and around the excavation limits of the incineration work.

- Determine the vertical and horizontal distribution of the peat layer encountered below the former Process and Tank Areas and at the base of the lagoon excavation.

- Understand the physical, hydrologic, and chemical characteristics of the peat layer beneath the former lagoon, especially its hydraulic conductivity and chlorinated solvent content.

- Determine the vertical and horizontal distribution of the Constituents of Potential Concern (COPCs) in former source areas (Process Area, Tank Area, Lagoon). COPCs include chlorinated solvents (i.e., PCE, TCE) nonchlorinated solvents (BTEX), lead, and PCBs.

- Evaluate the Pepper Building for potential residual sources of contamination.

- Screen for DNAPL below the former Process and Tank Areas and the former lagoon.

Characterization of the secondary sources of contamination associated with the former primary sources of contamination is necessary to evaluate: the risks posed by the site currently and in the future; the reduction in toxicity, mobility, and volume resulting from the treatment of lagoon materials; the probable effectiveness and implementability of potential remedial alternatives; and reasonable restoration timeframes, considering the difficulty of remediating LNAPL (and, if present, DNAPL) which is trapped at least in part below the water table.

Objective 3 - Establish the Vertical Distribution and Characteristics of the Fill, Ash and Lime, and Cover Material Layers in the Former Lagoon

Data and Technical Evaluation Needs:

In order to complete the closure of the incinerator ash management unit and determine the hydrology in the former lagoon area, additional data are needed to augment the existing information.

- Detail the as-built specifications of the residuals placed into the lagoon during Phase I, including the thickness and elevation of each layer placed in the former lagoon and how the thickness varies.

- Determine the physical, chemical, and hydrologic characteristics of the materials and/or layers in the former lagoon.

Objective 4 - Determine the Distribution and Gradients of COPCs Along Potential Exposure Pathways Under Current Site Conditions

The substantial changes in the site conditions would naturally result from the lagoon incineration work and the associated ground water pumping. These changes will have altered the hydrology and influenced the distribution and concentration gradients of COPCs in the vicinity of the former lagoon. The data for the site are at least 5 to 8 years old and several data gaps are now apparent. The data needs to determine current conditions for specific areas of the site are summarized below.

Off-Property Soils (Beyond BROS Property)

Data and Technical Evaluation Needs:

- Determine background soil quality by soil sampling at multiple locations (e.g. peach orchard and southeast of Route I-295).

- Survey the BROS property to determine the precise property boundaries.

- Delineate the vertical and horizontal distribution of site-related constituents which extend beyond the BROS property. This is especially important near Cedar Swamp Road and U.S. Route 130.

Gaventa and Swindell Ponds

Data and Technical Evaluation Needs:

- Complete the evaluation of the distribution of Constituents of Potential Ecological Concern (COPECs) as well as the gradients of COPECs in surface water and sediments in

the northwest corner of Gaventa Pond. Given the age of some data it is important to confirm the previous analytical results for Swindell Pond.

- Evaluate the hydrologic conditions and interactions between Gaventa and Swindell Ponds, ground water and the Little Timber Creek Swamp.

Little Timber Creek Swamp - Between Interstate Route 295 and U.S. Route 130 and Between U.S. Route 130 and Cedar Swamp Road

Data and Technical Evaluation Needs:

- Wetland delineation.
- Identify the vertical and horizontal distribution of COPECs in sediment.
- Understand the surface water flow pattern or patterns in the swamp.
- Identify and compare the horizontal distribution of COPECs in surface water as related to and compared with sediment concentrations.
- Identify the key species utilizing the swamp and determine the assessment endpoints.
- Identify the distribution of key species in relation to surface water and sediment concentrations.
- Characterize the areas dominated by *Phragmites* which contain residual LNAPL in sediment for evaluation of restoration alternatives as part of the Feasibility Study.
- Identification and characterization of reference areas.

Little Timber Creek Swamp - Between Cedar Swamp Road and the Tide Gate Along Route 44

Data and Technical Evaluation Needs:

- Wetland delineation.
- Identify the vertical and horizontal distribution of COPECs in sediment.
- Identify the key species utilizing the swamp and determine the assessment endpoints.

- Evaluate the concentration gradients of COPECs in the downstream direction of Little Timber Creek. Identify the horizontal distribution of COPECs in surface water as related to sediment concentrations.

- Identify the horizontal distribution of key species in relation to surface water and sediment concentrations.

Cedar Swamp - Downstream of the Tide Gate.

Data and Technical Evaluation Needs:

- Wetland delineation.

- Evaluate the presence or absence of COPECs in depositional areas along the drainage channel downstream of the tide gate.

Ground Water - Upper PRM and Recent Alluvium

Data and Technical Evaluation Needs:

- Determine the current concentrations of COPCs representative of ground water quality after the conclusion of the lagoon work and determination of ground water flow near the former lagoon under existing hydrogeologic conditions.

- Vertical and horizontal distribution of COPC beneath Little Timber Creek Swamp.

- Horizontal distribution of COPCs beneath the former lagoon.

- Concentrations of COPCs possibly discharging to surface water in Little Timber Creek Swamp.

- Potential for sediment contamination to mobilize and influence ground water quality during periods when surface water recharges ground water.

- Horizontal distribution of dissolved COPCs in the former Process and Tank Areas.

- Evaluate the potential occurrence of DNAPL below the former Process and Tank Areas and the former lagoon.

Ground Water - Upper Confining Layer

Data and Technical Evaluation Needs:

- Evaluate the vertical and horizontal extent of the strata beneath the former Process and Tank Areas, the former lagoon, the Little Timber Creek Swamp adjacent to the BROS property and to the north of Route 130.

- Determine concentrations and vertical distribution of COPCs in soils of this confining layer.

Ground Water - Upper Middle PRM

Data and Technical Evaluation Needs:

- Concentrations of COPCs representative of current ground water quality conditions.

- Vertical distribution of COPCs within the aquifer, especially below and near the former lagoon.

- Evaluate the potential occurrence of DNAPL below the former lagoon area.

- Horizontal distribution of COPCs beneath Little Timber Creek Swamp adjacent to the BROS property and between Interstate Route 295 and Swedesboro-Paulsboro Road.

Objective 5 - Establish the Degree of Hydraulic Connections Between the Aquifers and Surface Water

Data and Technical Evaluation Needs:

- Evaluate seasonally the flow direction and probable magnitude of flow between Swindell and Gaventa Ponds and the Upper PRM and Upper Middle PRM.

- Evaluate seasonally the flow direction and probable magnitude of flow between the Upper PRM and the Little Timber Creek Swamp.

- Determine the influence of pumping ground water in the Upper PRM on the Little Timber Creek Swamp, the adjacent ponds, and the Upper Middle PRM beneath the former lagoon.

- Determine the influence of pumping ground water in the Upper Middle PRM on the Little Timber Creek Swamp, the adjacent ponds, and the Upper PRM around the former lagoon. The degree of hydraulic interconnection between the Upper PRM and Upper Middle PRM will need to be specifically evaluated near the former lagoon.

These data will also be used in the water budget analysis, fate and transport assessment of COPC, and feasibility study.

Objective 6 - Establish the Hydrogeologic and Chemical Relationship Between the Chemical Leaman Tank Lines (CLTL) Site and BROS site

Data and Technical Evaluation Needs:

- Evaluate the hydrogeology of the CLTL site to determine the interaction, if any, between the two sites and potential effects of the CLTL ground water remedial system on ground water flow and contaminant fate and transport at the BROS site.

- Determine the extent of the clay confining layer between the Upper PRM and Upper Middle PRM in the area between the CLTL property and the BROS property.

- Evaluate the chemical constituents of concern associated with the CLTL site as compared or contrasted to those associated with the BROS site.

- At the direction of USEPA, evaluate the vertical and horizontal extent of CLTL-related constituents to assess whether potential remedial technologies at the BROS site will influence the remedial action at the CLTL site (for example, through mobilization of contaminants or alteration of extraction system capture zones).

Objective 7 - Assess the Environmental Fate and Transport of COPCs Under Current Site Conditions and Assess the Future Fate and Transport of COPCs

The Phase 2 RI/FS is a retrospective study, meaning the release of contaminants from the BROS waste oil operation occurred primarily in the past and the primary sources of contamination have been removed. Consequently, the mass loading of contaminants into potential exposure pathways has been decreased substantially and will continue to decline in the future. Under such conditions, the most direct way to evaluate the environmental fate and transport of COPC is to measure the concentration trends along exposure pathways over time at various points along concentration gradients of contamination. However, assessment and modeling of various factors that affect the rate of natural attenuation must also be evaluated separately, including: the biological and chemical degradability of the contaminants, the physical and chemical characteristics of the media, and physical characteristics of the geological medium. The data needs identified below relate to completing the fate and transport assessment of COPCs under current and future conditions.

Data and Technical Evaluation Needs:

- Determine if the distribution of site-related constituents in the Upper PRM and Upper Middle PRM is expanding, stable or decreasing.
- Identify the physical and chemical characteristics that impact the evaluation of the natural attenuation mechanisms and processes in various environmental media.
- Estimate the rates of degradation of the organic COPC in various media and in various portions of the site.
- Determine the chemical and biological degradability of the contaminants under the various physical and chemical characteristics present at the site.
- Characterize the mechanisms of sequestration of COPC and identify the adsorptive and exchange capacities of the various media and across the site.
- Determine the physical characteristics of the geological media as necessary to assess and model the environmental fate and transport of the COPC.
- Based upon the results of additional chemical, hydrologic, and stratigraphic evaluations, evaluate the rate of chemical transport in different geologic media encountered below the site using column leaching studies.

Objective 8 - Determine Representative Exposure Point Concentrations and Characterize Potential Receptors

A large amount of data has been generated for the site over the past twenty years. However, to accurately estimate the exposure point concentrations and the risks arising from those concentrations, the exposure point concentrations must be specifically measured in a manner that can be related directly to current or potential future receptors, human or ecological (USEPA, 1998f). Exposure estimates must be conservative but within a realistic range of exposure, where unlikely exposure scenarios are eliminated from consideration consistent with USEPA policy and guidance (USEPA, 1995). In considering land use and ground water use, Superfund exposure assessments most often classify land use into one of three categories (1) residential, (2) commercial/industrial, and (3) recreational; and ground water use is classified as potable or non-potable use.

In May 1997, the Settling Defendants reached an agreement with the owners of the BROS property that three perpetual deed restrictions in the form of Declaration Restrictive Covenants

would be promptly established for the BROS property, which include the Pepper Building, the former Lagoon and former Process Areas. These deed restrictions are currently in place and properly recorded. The provisions of the restrictions include:

- Future use of the property excludes residential use and limits other uses to non-retail commercial and/or industrial use. These uses are consistent with the use at the time the release of hazardous substances began.

- All subsurface activities (e.g., digging) are prohibited without prior written approval of the USEPA and NJDEP.

- The installation and/or use of any ground water wells at the site is prohibited without prior written approval of the USEPA and the NJDEP.

Beyond the BROS property, ground water use throughout the site is limited because most residents have connected to the municipal water supply which has also been made available to residents near the site. Consequently, the portion of the site beyond the BROS Property boundary area will be considered a potential future potable supply source but the current use risk assessment will be based on conditions established as part of this scope of work.

Data and Technical Evaluation Needs:

- Identify current and probable future ground water users that have the potential to be exposed to site-related contaminants.

- Determine representative human health risk assessment exposure point concentrations across various portions of the site in a manner consistent with current and future land use and/or water use.

- Identify ground water users and well configurations at the BROS site. Sample local private wells to evaluate the current extent and gradients of site-related COPCs in ground water and to assess representative COPC concentrations at potential receptor wells.

- Determine representative exposure point concentrations for key ecological receptors across various portions of the site.

- Annually evaluate the planned future use of land, especially land development proposals in the vicinity of the site by contacting the Logan Township Planning Board periodically throughout the duration of the Phase 2 RI/FS.

Objective 9 - Establish a Range of Remedial Alternatives that are Protective of Human Health and the Environment and Conduct Screening of Alternatives

In establishing the NCP-required range of remedial alternatives, several specific factors will be taken into account, including:

- there are various portions of the site where the distribution and composition of contamination varies and where the potential receptors may vary;

- guidance materials on the conventional methods, strategies, and technologies for ground water and volatile organic compounds in soils that are available (USEPA, 1993e; USEPA, 1996c);

- a variety of site-specific factors, such as LNAPL trapped below the water table and DNAPL (if present) , may make remediation impracticable by conventional methods and technologies;

- there are potential adverse effects on sensitive ecological environments from some remedial alternatives;

- there are human health risks posed by various remedial alternatives;

- a limited number of site-related constituents pose the majority of the risks in various media and the evaluation will need to consider the costs and benefits of reducing the principal and secondary risk factors;

- the effect of the CLTL remedial activities on the aquifers beneath the BROS Site;

- in Little Timber Creek Swamp, the areas dominated by *Phragmites* and containing elevated concentrations of site-related constituents are recognized at the start as probably requiring remedial action;

- institutional controls that may be developed or are already in place, such as ground water Classification Exception Areas and deed restrictions on the Borelli property;

- detailed evaluation of reasonable restoration times may be necessary in light of site-specific treatment limitations;

- a combination of remedial technologies and options as well as a phased remedial approach may be necessary to further reduce the toxicity, mobility, or volume of the remaining contamination, taking into account the treatment of wastes already completed.

In order to take these factors into account and develop an integrated remedial approach to the site, the data needs identified under the preceding objectives will be iteratively added into the feasibility study components.

Objective 10 - Conduct Relevant Treatability Studies

Based on data needs identified during the development and screening of remedial alternatives, treatability studies may be designed and conducted to reduce the uncertainty of whether some remedial technologies are feasible. Treatability studies will be described in a Technical Memorandum submitted to the USEPA after initiation of the field activities with the objective to complete the studies in time to be included in the FS Alternative Evaluation and in the Phase 2 RI/FS report.

Objective 11 - Complete the Cultural Resources Survey Requirements

Supplement the Stage 1A Cultural Resource Survey (CRS) to include the entire BROS site and conduct a Stage 1B CRS based on the previously completed Stage 1A CRS and the results of the supplemental Stage 1A CRS.

Phase 2 RI/FS Scope of Work

Consistent with the Phase 2 RI/FS objectives, the NCP, and the BROS Consent Decree, the scope of work is divided into nine tasks. Detailed descriptions of each task and the activities and deliverables to USEPA are provided in the Work Plan.

Task I - Scoping

- Process leading to USEPA approval of the Work Plan, Quality Assurance Plan, Sampling and Analysis Plan, and Health and Safety Contingency Plan.

- Preparatory activities such as the site property access agreements and the Stage 1B Cultural Resources Survey and Analytical Method Development.

Task II - Community Relations

- USEPA-lead activity to inform the stakeholders and seek their input.

Task III - Site Characterization

- Process of determining the distribution and potential movement of site-related constituents in relation to potential receptors.

Task IIIA - Field Investigations

- Activity 1 - Water Budget Evaluations
- Activity 2 - Soils Investigation
  - Activity 2a - Background and Off-Property Soils
  - Activity 2b - On-Property Soils
- Activity 3 - NAPL Investigation
- Activity 4 - Ground Water Investigation
- Activity 5 - Surface Water and Sediment Quality Evaluation
- Activity 6 - Human Health Exposure Point Concentration Evaluation
- Activity 7 - Ecological Evaluations

Task IIIB - Data Analysis

Task IIIC - Data Management Procedures

Task IIID - Site Characterization Deliverables

Task IV - Identification of Candidate Technologies

- Identification of the range of technologies required for alternative analysis.

Task V - Treatability Studies

- Evaluate the need for, and where necessary provide the scope of treatability studies, conduct the testing, and provide the results for use in the evaluation of remedial alternatives.

Task VI - Baseline Risk Assessment

- Determine the risks posed by any remaining contamination at the site to human and ecological receptors at the site. Results are used in the feasibility study to focus remedial alternatives on the principal risks and provide the basis to calculate the probable risk reductions associated with remedial alternatives as well as the risks posed by the alternatives (USEPA, 1998f).

Task VIA- Human Health Risk Assessment

Task VIB - Ecological Risk Evaluation

Task VII - Draft Remedial Investigation Report

- Summarizes the field activities and findings which characterize the site and includes the human health and ecological risk assessments.

Task VIII - Development of Remedial Action Objectives and Screening of Remedial Alternatives

- The development and screening of remedial alternatives is performed to develop an appropriate range of risk and waste management options that will be evaluated. This range of alternatives will include as appropriate, options in which treatment is used to reduce the toxicity, mobility, or volume of wastes, but varying in the types of treatment, the amount treated, and the manner in which long-term residuals or untreated wastes are managed; options involving containment with little or no treatment; options involving both treatment and containment; and a no-action alternative.

Task VIIIA - Development and Screening of Remedial Alternatives

Task VIIIB - Conduct and Document Screening Evaluation of Each Alternative

Task VIIIC - Presentation of Remedial Action Objectives and Development and Screening Alternatives

Task IX - Feasibility Study Report

- The final RI/FS task is the detailed analysis of alternatives which is conducted through the application of nine evaluation criteria to the assembled remedial alternatives. The approach will ensure that the selected remedial alternative(s) will be protective of human health and the environment; will be in compliance with, or include a waiver of, ARARs; will be cost-effective; will utilize permanent solutions and alternative treatment technologies, or resource recovery technologies, to the maximum extent practicable; and will address the statutory preference for treatment as a principal element, taking into account the treatment already completed at the site. The evaluation criteria include: (1) overall protection of human health and the environment; (2) compliance with ARARs; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, or volume; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state (or support agency) acceptance; and (9) community acceptance. (Note: Criteria 8 and 9 are considered after the Phase 2 RI/FS report has been released to the general public.)

  Upon completion, a draft FS report will be submitted to USEPA for review and approval. Once USEPA's comments have been addressed by the Defendants to USEPA's satisfaction, the final FS report will be bound with the final RI report.

Task IXA - Detailed Analysis of Alternatives

The detailed analysis will include a comparative analysis of the remedial alternatives in which each alternative will be compared against the others using the evaluation criteria as a basis of comparison. Identification and selection of the preferred alternative(s) will be completed by the USEPA.

Task IXB - Detailed Analysis Deliverables

Schedule

A detailed schedule for the Phase 2 RI/FS has been prepared consistent with the EPA-approved schedule (Plate 1). The overall project schedule is predicated on receipt of USEPA approval of this revised Phase 2 RI/FS Work Plan (and the QAPP, SAP and HASP) by mid-January 1999. An

additional two months are projected for completion of a public meeting to provide for public participation in the Phase 2 RI/FS scoping process.

The overall schedule is driven by the seasonal sensitivity of the aquifer pumping tests and ecological risk assessment (ERA) field data collection efforts. Specifically, the aquifer tests should be performed during the driest period of the year, late summer, to provide a basis for predicting the influence of ground water extraction on the wetlands. Information from the CLTL extraction system and available regional hydrology data can then be used for the conceptual design of a pumping system that will be effective during wetter periods. This information will be used for the design and evaluation of remedial alternatives.

Based on USEPA comments, the ERA data collection must be conducted during two periods representing both wet and dry conditions in the wetland areas. As such, data collection will be completed in two phases, one between April and June, and the other between August and early October. In addition to providing both wet and dry season data, these periods correspond to the time when tree canopy cover is established, juvenile amphibians have matured to identifiable life stages, winter migrants have returned and the maximum numbers of aquatic macroinvertebrates are present.

An advantage of the proposed schedule is that it provides for subsequent phases of the RI delineation efforts, to the extent necessary. Subsequent phases of RI field work can be more readily accommodated if Work Plan approval occurs by January 1999.

Completion of the work in accordance with the schedule will be dependent upon the following:

- the timing of the USEPA approval of the Phase 2 RI/FS Work Plan (and the Quality Assurance Plan, Sampling and Analysis Plan, and Health and Safety Contingency Plan);
- obtaining access to properties for sampling;
- review, comment, and approval periods for the interim project deliverables (e.g. technical memoranda) throughout the process;
- the flexibility in the schedule to conduct aquifer pumping tests and ecological risk evaluations during late summer when the general data will be most decision relevant; and
- the need for any subsequent phases of field investigation to complete the RI, especially the ecological risk evaluation of Little Timber Creek.

1.0 INTRODUCTION

The Bridgeport Rental and Oil Services (BROS) Superfund Site is located on Cedar Swamp Road in Logan Township, Gloucester County, New Jersey. At various times, the current and previous owners and operators used the site for several purposes, including waste oil reprocessing, waste disposal, and waste storage. The United States Environmental Protection Agency (USEPA) placed the site on the National Priorities List on September 8, 1983 (See 48 Fed. Reg. 40, 658) and commenced a Remedial Investigation and Feasibility Study (RI/FS).

The RI/FS identified several sources of contamination and various contaminated areas. On December 31, 1984, USEPA issued a Record of Decision (ROD) which called for: (1) installation of a water supply line to replace private water supplies near the site; (2) dismantling of the tank farm at the site; (3) excavation and on-site incineration of lagoon sediment; and (4) performance of a Phase 2 RI/FS to address ground water at and emanating from the site.

Two major law suits were filed with regard to the BROS site. On March 20, 1992, thirteen private parties filed suit in *Rollins Environmental Services (NJ) Inc., et al. v. United States, et al.* against the United States Department of Defense and certain named departments and agencies (including the Defense Logistics Agency and the Departments of the Army, Air Force, and Navy) and certain private parties. On June 30, 1992, the Unites States of America, on behalf of USEPA, filed a complaint against a number of corporate defendants in *United States v. Allied Signal, Inc.* The complaint was amended on November 30, 1992 (USDC, 1997a).

On October 2, 1992, the Court consolidated the *Allied Signal* and *Rollins* cases. On March 31, 1993, the State of New Jersey, Department of Environmental Protection (NJDEP) intervened in the *Allied Signal* action as a plaintiff. In May 1993, the *Allied Signal* defendants counter-claimed against NJDEP and asserted claims against the New Jersey Department of Military and Veterans Affairs and the New Jersey Department of Transportation.

The *Rollins* and *Allied Signal* cases were essentially resolved by a Consent Decree entered by the Court on January 17, 1997 (USDC, 1997a). Under that Consent Decree, which provided for financial contributions to the ongoing BROS cleanup from federal, state, and private PRPs; the Settling Defendants, including a number of private parties allowed by the Court to intervene as defendants in the *Allied Signal* action for the purpose of participating in the Consent Decree, assumed responsibility for implementation of the Phase 2 RI/FS activities intended to identify remedial actions for ground water and wetlands.

The BROS Technical Committee, composed of senior managers employed by certain Settling Defendants, selected Environmental Liability Management, Inc. as the Project Coordinator and Roux Associates, Inc. as the contractor to develop and implement the Phase 2 RI/FS activities. These activities are outlined in the Statement of Work in the Consent Decree and detailed in this Work Plan and its associated documents. The information generated and compiled during the Phase 2 RI/FS, including public participation, will be used by USEPA to select a remedial action or actions for ground water and wetlands. These remedial actions may include actions to address the residual contamination in the soils at the BROS property and final closure of the incinerator ash management unit. USEPA will describe the scope of these actions and how they were selected in a Phase 2 Record of Decision (ROD).

The purpose of the Phase 2 Remedial Investigation/Feasibility Study (RI/FS) Work Plan is to describe the tasks and the supporting rationale for the proposed assessment of site conditions and evaluation of alternatives to the extent necessary to select a remedy for the Bridgeport Rental and Oil Services (BROS) Superfund site. This Work Plan was developed based upon evaluations during the scoping process, including a review of available data from prior investigations and remedial actions at the site. In addition, in preparing the Work Plan Roux Associates, Inc. consulted and relied upon the National Contingency Plan (NCP, 1990), the New Jersey Technical Requirements for Site Remediation (N.J.A.C. 7:26E), and the United States Environmental Protection Agency (USEPA) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a). Other documents were concurrently developed and

are cross-referenced in the Work Plan, including the Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan (SAP), and Health and Safety Contingency Plan (HASP).

The general objectives of the Phase 2 RI/FS are outlined below, based upon the requirements of the Consent Decree (USDC, 1997a). Specific objectives and associated Phase 2 RI/FS data needs are presented in Section 5.0.

A primary objective of the Phase 2 RI study is to collect the data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives, building from the previously conducted studies. In addition, the RI site characterization will provide the information for completion of a site-specific baseline risk assessment which will evaluate the current and potential threats to human health and the environment that may be posed by the contaminants being transported to ground water or surface water, releasing to the air, leaching through the soil, remaining in the soil, or bioaccumulating in the food chain. The risk assessment will be used to support the development, evaluation, and selection of appropriate response alternatives in the FS.

The primary objective of the FS will be to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker and an appropriate remedy selected. Development of the alternatives will be fully integrated with the site characterization activities of the RI and the results of the risk assessment. Alternatives will be developed to protect human health and the environment by eliminating, reducing, and/or controlling unacceptable risks through each pathway associated with the entire site and specific areas of concern or hot spots. In accordance with Risk Assessment Guidance for Superfund - Human Health Evaluation Manual, Part C: Risk Evaluation of Remedial Alternatives (USEPA, 1991e), the risk associated with potential remedial alternatives will be evaluated and considered in the FS process. Detailed analysis of the short-term and long-term risks will follow the same general steps as the baseline risk assessment (USEPA, 1998f).

Ultimately, the information compiled and generated during the Phase 2 RI/FS will be used to support the selection of a remedial action or actions for ground water and wetlands. The rationale for the decision, consistent with CERCLA and the NCP, will be described in the Phase 2 Record of Decision (ROD).

2.0 SITE DESCRIPTION AND ENVIRONMENTAL SETTING

2.1 Site Description and Surrounding Land Use

The BROS Superfund Site is located in Logan Township, Gloucester County, New Jersey, approximately one mile east of the town of Bridgeport and west of the divergence of U.S. Route 130 and Interstate 295 (Figure 1). As defined in the Consent Decree (USDC, 1997a), the site includes the areal extent of the contamination relating to the release or threatened release of hazardous substances and all suitable areas in very close proximity to the contamination necessary for implementation of response activities, which includes in its entirety the BROS property where the operations occurred that led to the release of hazardous substances (Figure 1). These definitions of the BROS site and the BROS property will be applied throughout the Work Plan. As additional delineation of site-related contamination is completed, the boundaries of the site may change. Site features include remnants of the historical sand mining, waste oil storage and recovery, and storage tank leasing operations conducted at the site.

The BROS property and surrounding area (Figure 2) are relatively level topographically. The BROS property is generally covered with topsoil and grass, except along the northern boundary, which is the location of a gravel driveway and parking area, and where some structures are located. The BROS property includes:

- the former 13-acre waste oil and wastewater lagoon, which has been filled as part of remedial activities, situated along the southern and western site boundaries;
- the former storage tank farm and process areas situated between the former lagoon and the northern property boundary along Route 130;
- the low-lying area between the former lagoon and the marsh situated along the eastern edge of the site;
- an inoperative aqueous wastewater treatment system (AWTS) that was used to treat liquids pumped from the lagoon during remedial activities;

- two office trailers and several storage trailers;
- a warehouse building situated near Cedar Swamp Road and referred to as the Pepper Building;
- the peninsular area situated between the Gaventa Pond, Swindell Pond, and Little Timber Creek Swamp which, along with the lagoon, was mined during the former sand mining operations; and
- an area of ground water contamination which extends to the southeast of Route I-295.

Commercial operations were terminated at the site over 15 years ago and, as described in more detail in Section 2.2, remedial actions conducted at the site under the direction of the U.S. Army Corps of Engineers (USACOE) included demolition and removal of the tank farm and dewatering, excavation, and backfilling of the lagoon materials, to the extent practical in the vertical direction.

The BROS property is located two miles south of the Delaware River, and Cedar Swamp extends from north of the property to the Delaware River. As such, much of the land is undeveloped swamp and streams flowing northward to the river, interspersed with some agricultural and a few residential properties. The BROS property is bordered to the north by Cedar Swamp Road and U.S. Route 130, which traverse the Cedar Swamp on an earthen embankment. The Little Timber Creek and the associated Little Timber Swamp lie to the east of the BROS property. Gaventa Pond and Swindell Pond lie to the south, and a peach orchard is operated to the west of the BROS property. A truck repair garage and heavy equipment storage lot is located approximately 300 feet northwest, and three homes are located 800 feet north of the site on the other side of U.S. Route 130. The Chemical Leaman Tank Lines (CLTL) Superfund Site is an active industrial operation approximately one-half mile west of the site.

2.2 Site History

Sand and gravel dredging operations began at the BROS property in the late 1950s (Hart, 1982). Reportedly, the sand was used for New Jersey highway projects. Between the 1950s and 1960s, the surface area of the lagoon increased to a maximum size of approximately 13 acres and sand was mined below the water table to a maximum depth of approximately 25 feet below ground surface (BGS).

In the early 1960s, storage tanks and process vessels were constructed as part of waste oil processing, storage and disposal at the site. The storage tanks comprised a tank farm that consisted of up to 100 tanks and process vessels at the height of operations in the 1970s. From the 1960s into the 1970s, the site was used for waste oil storage and recovery and for storage tank leasing operations (USACOE, 1996). A review of historical aerial photographs indicates various liquids and oils were deposited into the lagoon from approximately 1960 to the early 1980s as part of the waste oil recovery/recycling operations (ERI, 1993).

In June of 1972, the eastern dike of the lagoon was breached by the liquid in the lagoon resulting in an area of stressed vegetation in the Little Timber Swamp. From 1975 to 1980, the New Jersey Department of Environmental Protection (NJDEP) initiated several enforcement actions against the owners of the BROS operation and property. In response to the enforcement actions by the NJDEP, the owners proposed and attempted various cleanup efforts.

Because the owners' cleanup efforts did not mitigate the potential for the future releases, the USEPA considered the cleanup efforts by the owners to be unsuccessful. Accordingly, commercial waste-handling practices were prohibited at the site by court order and, as described in detail in Section 2.3, the USEPA initiated response actions. Environmental concerns identified at the site by a USEPA contractor, NUS Corporation (1984), after the cessation of commercial operations included:

- a floating layer of oil on the lagoon;
- oily sediment/sludge at the bottom of the lagoon;

- tank wastes; and

- soil, surface water, and sediment contamination resulting from lagoon seeps and overflows, and from spillage of wastes in and around the tank farm (NUS, 1984).

Since the early 1980s, the only activities at the site have been remedial investigations and remedial actions undertaken to address the environmental concerns associated with the site.

2.3 Previous Site Investigations and Remedial Actions

Several investigations, remedial activities, and administrative actions have been conducted at the BROS site since the early 1980s. An overview of the previous site investigation results is provided later in this section. A chronology of some of the site-related environmental investigations and activities after January 1, 1980 is provided below.

- Between October 1980 and July 1981, the USEPA Field Investigation Team (FIT) of Fred C. Hart Associates, Inc. (Hart) performed a hydrogeologic investigation in the vicinity of the BROS property. The study included the installation of, and ground water sample collection from, eight shallow and one deep monitoring well screened in the Upper Potomac-Raritan-Magothy (PRM) and Upper Middle PRM, respectively (Hart, 1982).

- In the Spring of 1981, liquid levels in the lagoon rose and threatened to overflow the lagoon dike. In response to this threat, the U.S. Coast Guard increased the height of the lagoon dike by approximately five feet (USACOE, 1996).

- In October 1981, the NJDEP installed one monitoring well to the base of the Upper Middle PRM in the adjacent peach orchard (Hart, 1982).

- In the Spring of 1982 and 1983, the liquid levels in the lagoon rose again and threatened to overflow the new dike. During these two periods, the USEPA initiated emergency response action and lowered the level of the lagoon by pumping aqueous phase liquids from the lagoon through a mobile carbon treatment system (USACOE, 1996).

- In the September 1983, pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the USEPA placed the BROS site on the National Priorities List (NPL) (USDC, 1997a).

- In 1983 and 1984, the USEPA contracted NUS to complete the Phase 1 Remedial Investigation (RI)/Feasibility Study (FS) at the BROS site. NUS installed 17 monitoring wells into the Upper and Upper Middle PRM and two deep borings to 180 and 230 feet BGS. The monitoring well network included four 3-well clusters and five single wells (NUS, 1984).

- In 1984, the USEPA contracted Camp Dresser and McKee (CDM) to design a lagoon liquid treatment system and EMPAK, Inc. to construct and operate the system, which consisted of water extraction pumps, an oil/water separator, flocculation/sedimentation tanks, and sand and granular activated carbon filters. The system was used to lower the lagoon level by approximately eight feet and discharged treated effluent to Little Timber Creek (USACOE, 1996).

- In December 1984, the USEPA issued a Record of Decision (ROD) for the BROS site. Remedial Actions subsequently performed in accordance with the ROD included:

  - The design and installation of a potable water extension line to service potentially-impacted residences in the vicinity of the site. The work was completed under the oversight of the NJDEP between 1985 and 1987 (Personal communication with Michael McIntyre of the Pennsgrove Water Supply Company, June 22, 1998).

  - The demolition and removal of on-site buildings and approximately 100 tanks and process vessels used to store hazardous wastes in the tank farm and the off-site disposal of approximately 400,000 gallons of oils and sludges, 5,200 floating and buried drums, and 4,300 tons of debris. The work was conducted between 1986 and 1988 under the oversight of the USACOE.

- The construction of an on-site aqueous wastewater treatment system and permitting of an on-site transportable incinerator. The incinerator was used for the thermal destruction of over 172,000 tons of material including 138,350 tons of underlying lagoon sediments and sludges, 3,850 tons of lagoon oil, 12,550 tons of lagoon levee material, 4,250 tons of soil reportedly as a result of the lagoon overflows in previous years, and 13,000 tons of debris (USACOE, 1996). During excavation of the lagoon, over 190 million gallons of ground water was removed from the lagoon by pumping and treated using the AWTS prior to discharge to the Little Timber Creek. The lagoon was backfilled with sand, lime-treated ash, and stone to grade and is currently covered by topsoil and grass. The design and remediation activities for the lagoon remedial actions were performed between 1988 and 1996 under the oversight of the USACOE.

- In 1990, in addition to the Phase 1 ROD activities, drums of hazardous materials were removed from the Pepper Building by USEPA's Removal Branch.

- In 1990 and 1991 Phase 2 RI/FS activities were conducted by CH_2M Hill, under contract to the USEPA, to define the extent of soil and ground water contamination and to develop and evaluate remedial alternatives for the BROS site. CH_2M Hill conducted aquifer testing, tidal studies, surface water, sediment and ground water sample collection, and installed 22 wells. Eighteen wells were installed as two-well clusters and the remaining four wells were installed at locations and depths selected to augment the well clusters or address data gaps in the existing monitoring well network. Four of the clusters consisted of monitoring wells screened in the water table (Upper PRM) and Upper Middle PRM. Five of the clusters were comprised of couplets installed in the Upper PRM and the Lower Middle PRM. In 1993, CH_2M Hill installed eight additional wells downgradient from the existing monitoring well network to characterize the extent of ground water contamination. Wells were installed in pairs and screened in the Upper PRM and Upper Middle PRM.

- In September 1996, the Settling Defendants signed the BROS Consent Decree and agreed to implement the Phase 2 RI/FS activities as well as the ground water and wetlands remedial actions. The BROS Technical Committee, who are composed of representatives of the Settling Defendants, hired Environmental Liability Management, Inc. to serve as Project Coordinator. Roux Associates, Inc. was contracted by the BROS Technical Committee to develop and implement the additional Phase 2 RI/FS activities outlined in this Work Plan. The Phase 2 RI/FS organizational structure and project responsibilities are outlined in Section 8.0.

- Between November 1996 and February 1997 the USACOE, under the oversight of the USEPA, performed a Phase 3 soil investigation in the former Process and Tank Area (USEPA, 1998). Soil borings were reportedly completed to evaluate the potential presence of buried drums or debris based on a geophysical survey performed by USEPA contractors. This soil investigation is discussed in more detail in Section 2.5.1.1.

- In May 1997, as part of the negotiated settlement between the owners of the BROS property and Settling Defendants, three perpetual deed restrictions were established and properly recorded for the BROS property, which includes the Pepper Building, the former Lagoon and former Process Areas (USDC, 1997b). The provisions of the restrictions include:

  - Future use of the property excludes residential use and limits the other uses to non-retail commercial and/or industrial uses. These uses are consistent with the historical use of the property when the release occurred.

  - All subsurface activities (e.g., digging) are prohibited without prior written approval of the USEPA and NJDEP.

  - The installation and/or use of any ground water wells at the site is prohibited without prior written approval of the USEPA and the NJDEP.

2.4 Physical Setting

2.4.1 Physiography

The BROS site is located within the Atlantic Coastal Plain physiographic province approximately two miles south of the Delaware River. Topography of this portion of the Atlantic Coastal Plain is characterized by gently undulating plains with low relief. The area is dissected by marsh and swamp areas bounding the tributaries to the Delaware River. Site elevations range from near sea level to approximately 15 feet above mean sea level (amsl) (Figure 1).

2.4.2 Geology

The Atlantic Coastal Plain physiographic province is characterized by a southeastward-dipping wedge of unconsolidated sands, silts, and clays (Figure 3). Regionally, the units exhibit a northeast-southwest trending strike and often display rapid lateral facies changes and thickness variations. The unconsolidated sediments were deposited on a subsiding continental margin in a variety of marine and non-marine environments and range in age from lower Cretaceous to Holocene (Owens and Sohl, 1969). The detrital deposits overlie a pre-Cretaceous bedrock basement that is generally mantled with a saprolite clay layer.

The basement bedrock, the pre-Cambrian Wissahickon Formation, is comprised of gneiss and schists. Competent bedrock in the area is encountered at approximately 280 feet BGS. However, the depth to bedrock varies as the saprolite clay mantling the bedrock may attain 40 feet in thickness (Kozinski, 1990).

The Wissahickon Formation is unconformably overlain by the Potomac Formation, which ranges in thickness from 280 feet beneath the BROS site to 300 feet beneath Interstate 295. The Potomac Formation consists of light-colored, fine- to coarse-grained sand with variegated red and white silt and clay beds. The clay beds in the Potomac Formation vary in thickness laterally but generally thicken downdip from the site. The sands include quartz and orthoclase feldspar with trace amounts of mica, biotite, and opaque minerals. The sands of the Potomac Formation are coarser, but less well sorted and texturally mature, than those of the overlying Magothy Formation.

The Magothy Formation is separated from the Potomac Formation by a basal clay layer. The clay unit is continuous across the site, with the exception of monitoring wells S-11C and MW-1C where only a fining sequence was observed and reported (Figure 4). Zapecza (1984) notes that this confining bed locally in Gloucester County thins to less than 20 feet thick. To the west at the CLTL site, the clay unit is discontinuous and the zone between the Magothy and Potomac Formations is reported to be gradational (USEPA, 1990a). Above the clay layer, the Magothy Formation consists of fine- to medium-grained, well-sorted, white- to light-gray sand with occasional thin, intercalated, light- to dark-gray clay. The sands are comprised of approximately 90 percent quartz, with mica and lignite, and trace amounts of feldspar, heavy minerals, and pyrite. The Magothy Formation ranges from approximately ten feet thick below the former lagoon to between 50 to 70 feet thick below Interstate 295. Palynological data reviewed by the USGS indicated that the Late Cretaceous Raritan Formation is not present beneath the BROS site and that Magothy Formation unconformably overlies the Potomac Formation (Zapecza, 1984).

The Late Cretaceous Merchantville Formation is not found below the BROS property, but is located to the east of Interstate 295. The Merchantville Formation, in the vicinity of the BROS site, consists of glauconitic and mica-rich clays and silts (CH_2M Hill, 1996a) which is consistent with the description by Zapecza (1984). The Merchantville Formation thickens to the east and the unconformable contact between the Merchantville and underlying Magothy Formations dips approximately 25 feet per mile (CH_2M Hill, 1996a). The erosion of the clay in the Merchantville Formation by the Little Timber Creek may have transported and deposited the fines in Little Timber Swamp adjacent to the BROS property to form a confining layer between the wetlands and the underlying Magothy Formation. Further assessment of the stratigraphy of the wetlands is an objective of the Phase 2 RI/FS.

At the BROS property, the Cretaceous deposits are covered by surface sediments comprised of undifferentiated fill material and recent alluvium. The fill materials consist of construction debris including concrete and asphalt slabs, wood, glass, metal and brick mixed with fine- to medium-grained sand (CH_2M Hill, 1996a; USEPA, 1998). The fill materials range in thickness from zero

to 17 feet with the greatest accumulations encountered on the east side of the lagoon in boring MW-1C (CH_2M Hill, 1996a).

The Recent alluvial deposits consist of soft, green-gray, silty clay and medium- to fine-grained sand interbedded with brown peat. The alluvial deposits extend below the former lagoon area through the nearby wetlands area and Little Timber Creek. The alluvial deposits range in thickness from 0 to 19 feet (CH_2M Hill, 1996a). The textural composition and stratigraphy below Little Timber Creek and to the east of the Former Lagoon are currently unknown and will be investigated as part of the Phase 2 RI/FS.

The Cape May Formation is present in the vicinity of the site, primarily along streams to the southeast, and is comprised of gravel, fine- to coarse-grained, yellow or brown sands, and minor amounts of yellow, brown, and black clays. Near the BROS site, this unit ranges in thickness from zero to 10 feet. Where the Cape May Formation is composed of reworked Magothy Formation or Potomac Formation, it is difficult to differentiate from these underlying units.

In addition to the anthropogenic fill on the site, the former lagoon was backfilled as part of the lagoon Remedial Action. Upon completion of the dewatering and excavation activities, the former Lagoon Area was filled with sand, lime-treated ash, capped with gravel and top soil, and seeded with grass. The top soil cover was extended to cover the former incinerator handling areas and the extends across nearly all of the former Process Area.

The geology in the immediate vicinity of the former lagoon area is illustrated in two conceptual geologic cross sections which were constructed based on boring logs from the Phase 2 RI (CH_2M Hill, 1996a) and the Phase 3 RI (USEPA, 1998) (Figures 5 and 6).

2.4.3 Surface Water Hydrology

The BROS site lies in the Delaware River drainage basin. Adjacent to the site, the natural surface-water drainage patterns have been altered by Routes 130 and 295, other roads, man-made earthen embankments and drainage ditches associated with the roadways and farm fields. Surface

water drainage in the area generally trends from southeast to northwest toward the Delaware River. Due to the relatively flat topography of the BROS site, surface runoff drainage gradients are low (Figure 1).

The tributary to the Delaware River located closest to the BROS property is the Little Timber Creek. It is an intermittent stream south of Route 130 that does not have a defined channel east and north of the BROS property where it traverses Little Timber Creek Swamp. Although maximum tidal fluctuations of five feet have been measured in Little Timber Creek near its confluence with the Delaware River, a tidal gate eliminates most recognizable tidal fluctuations upstream of Cedar Swamp Road(CH_2M Hill, 1996a).

Including Little Timber Creek, nearby surface water bodies that receive drainage from the BROS property include:

- Little Timber Creek and Little Timber Creek Swamp, which currently receive drainage from the east side of the site and to which overflow from the former lagoon historically discharged;

- Gaventa Pond and Swindell Pond, which receive limited surface water runoff from the south and west sides of the BROS property; and

- Cedar Swamp, which receives surface water runoff from the ditches that drain the north side of the BROS property via Little Timber Creek and Little Timber Creek Swamp.

During extended periods of abundant precipitation, a direct surface water connection exists between Swindell Pond and Little Timber Creek Swamp to the east, but Swindell and Gaventa Ponds are not directly.

The Bridgeport, New Jersey area receives an average of 41 inches of precipitation annually (NUS, 1985). Of the 41 inches of precipitation per year, Watt and Johnson (1992) estimated evapotranspiration accounts for 15 to 22 inches per year, surface water runoff is approximately 2

inches per year, and recharge to the surficial aquifer system by percolation accounts for the remaining 17 to 24 inches. Rhodehamel (1970) estimates that approximately 85 percent of the ground water recharge in the Coastal Plain flow system is discharged as base flow to streams, with the remainder flowing into deeper aquifers. Given the variable nature of the surface water-ground water interactions, surface water bodies in the vicinity of the site serve as both recharge and discharge points for ground water base flow.

2.4.4 Ground Water Hydrology

For the purposes of assessing the stratigraphy and vertical distribution of contaminants in ground water, 62 monitoring wells or piezometers have been installed (CH_2M Hill, 1996a) and seven hydrogeologic units have been identified underlying the BROS site. These units include the Upper PRM aquifer, the confining bed between the Upper PRM and the Upper Middle PRM aquifers, the Upper Middle PRM aquifer, the confining layer between the Upper Middle PRM and the Lower Middle PRM aquifers, the Lower Middle PRM aquifer, the confining layer between the Lower Middle PRM and Lower PRM aquifers, and the Lower PRM aquifer. The existing monitoring well locations are illustrated in Figure 7 and their construction details are summarized (Table 1). To date, all hydrologic data has been obtained prior to or during the early stage of the lagoon removal project. Hydrologic information will be collected during the Phase 2 RI to assess the current conditions at the BROS site.

2.4.4.1 Upper PRM

The BROS site lies in the recharge area of the Upper PRM. At the site, the Upper PRM is under water table conditions. The Upper PRM has been characterized to consist of three hydraulically-connected lithologic units including, fill material, peat and sand in the alluvium, and sands of the Magothy Formation (CH_2M Hill, 1996a). The thickness of the Upper PRM ranges from ten feet beneath the former lagoon area to greater than 80 feet beneath Swedesboro-Paulsboro Road.

The geometric mean of hydraulic conductivity for the Upper PRM was calculated to be 21.1 feet per day, using the Bouwer and Rice Method for slug tests, with the hydraulic conductivity of the fill material in and around the former Tank and Process Areas even lower (CH_2M Hill, 1991a).

The peat layer had significantly higher permeability; however, only one sample was analyzed for geotechnical parameters. Additional geotechnical analyses of the fill material, the Magothy Formation and the peat will be completed as part of the Phase 2 RI to more fully evaluate the hydrologic properties of these units.

At the BROS site, ground-water flow patterns in the Upper PRM are relatively complex and largely controlled by surface water-ground water interactions. Historically, the liquid elevations in the waste lagoon were higher than ground water in the adjacent formations. Shallow groundwater generally flowed radially in the immediate vicinity of the lagoon toward the adjacent wetlands and recharged the Upper PRM. Ground water flow direction varied with seasonal water table fluctuations and dewatering operations which lowered water-level elevations in the lagoon from 15 feet amsl to less than 2 feet amsl.

Hydraulic gradients away from the lagoon decreased and ground water flow directions varied as dewatering occurred between 1988 and 1991 and intensified between 1991 and 1993 (CH_2M Hill, 1996a). During the height of dewatering operations between 1993 and lagoon closure in 1996, the lagoon served as a discharge point for the Upper PRM and the surrounding surface water bodies. The post-closure flow patterns and gradients in the vicinity of the former lagoon are currently unknown and will be assessed during the Phase 2 RI/FS activities outlined in this Work Plan.

Excluding the effects of the lagoon backfill material, current ground water flow directions near the BROS property follow the regional flow patterns in the outcrop area of the Upper PRM. That is, ground water generally follows topography and discharges to local surface water bodies and wetlands (Modica et al. 1997). Based on historical site data (CH_2M Hill, 1996a), Gaventa Pond is a ground water discharge point during dry months but recharges the water table aquifer during the wetter months of Spring. Conversely, Swindell Pond appears to maintain higher water-level elevations and probably recharges the Upper PRM throughout much of the year.

In the downdip portion of the Upper PRM south of Interstate 295, the Upper PRM is overlain by the Merchantville Formation and ground water flows to the southeast consistent with the regional flow direction along a horizontal gradient of 0.001 feet/foot (ft/ft). South of Interstate 295, the Upper PRM becomes confined between the basal silty-clay layer and the outcrop of the Merchantville Formation. Generally, the basal confining unit is continuous beneath the Upper PRM. The reported vertical gradients between the Upper PRM and the Upper Middle PRM were downward in 12 well clusters (ranging from 1.2×10^{-2} and 8.6×10^{-3} ft/ft) and upward in two well clusters (2.8×10^{-2} ft/ft at S-3A/S-3B and 8.3×10^{-3} ft/ft at MW-12A/MW-12B). No vertical gradient was observed at MW-6A/EPA-103.

2.4.4.2 Confining Layer Between Upper PRM and Upper Middle PRM

Geologic and natural gamma logs for the site monitoring wells indicate that the confining layer between the Upper PRM and Upper Middle PRM is generally continuous throughout the study area and dips to the south-southeast. The thickness and characteristics of the confining layer vary across the site with a cumulative thickness of approximately 15 feet, consisting of stacked interbedded clays, beneath the southwest side of the lagoon to only a six-foot thick fining sequence of silts in monitoring wells S-11C and MW-1C to the southeast (CH_2M Hill, 1996a). The fining sequence/clay layer was identified in the natural gamma log around 15 to 20 feet in MW-7B to the north of the BROS property and at 26 to 30 feet in MW-3C off the northwestern corner of the BROS property. On the CLTL site to the west, no continuous confining layer was encountered (USEPA, 1990a) and none was detected in BROS monitoring well S-9; however, EPA 108 located to the west encountered clay near 30 feet. Also, no clay confining layer was noted in the boring log for MW-9B and MW-10B suggesting that the recent alluvial deposits have replaced the eroded upper PRM below the Little Timber Creek Swamp to the east of the former BROS lagoon. Zapecza (1984) mapped the confining bed between the middle and upper aquifers in the PRM at approximately 50 feet in the vicinity of the BROS site. Shelby tubes collected from the confining layer had a geometric mean vertical hydraulic conductivity value of 0.00018 feet per day (CH_2M Hill, 1996a). Additional investigation of the physical and geotechnical characteristics

of the confining unit below the former BROS lagoon and in the Little Timber Creek Swamp, to the east, will be performed during the Phase 2 RI.

2.4.4.3 Upper Middle PRM

The Upper Middle PRM is a semi-confined aquifer that ranges in thickness from 90 feet northwest of the former lagoon to 40 feet downdip near MW-16B. A comparison of barometric pressure fluctuations relative to ground water elevations in the Upper Middle PRM also suggests that the Upper Middle PRM is a semi-confined aquifer. Dewatering of the former lagoon had no significant effect on the potentiometric surface or hydraulic gradients within the Upper Middle PRM, further indicating the semi-confined nature of this aquifer (CH_2M Hill, 1996a).

Hydraulic gradients within the Upper Middle PRM range from an approximate mean of 0.00043 ft/ft near the former lagoon to 0.002 ft/ft near Swedesboro-Paulsboro Road. Aquifer transmissivities and hydraulic conductivities also increase in a downdip direction. The geometric mean of hydraulic conductivity for the Upper Middle PRM was calculated to be between 10.5 to 40.7 feet per day (CH_2M Hill, 1996a). A mean hydraulic conductivity that is approximately twice that of the rest of the aquifer material was calculated for the 5-foot thick gravel layer that lies upon the basal confining unit. CH_2M Hill (1996a) reported a consistent downward vertical flow gradient within the Upper Middle PRM ranging between 2.3×10^{-3} and 4.5×10^{-3} ft/ft. The vertical gradient between wells within the Upper Middle PRM and the Lower Middle PRM was downward in three clusters, ranging from 1.3×10^{-2} to 9.4×10^{-3} ft/ft, and upward at S11-C/MW-1C where the gradient was 2.5×10^{-3} ft/ft.

2.4.4.4 Confining Layer Between Upper Middle PRM and Lower Middle PRM

A generally continuous confining layer, consisting of red-grey silty clay, separates the Upper Middle PRM and Lower Middle PRM aquifers across most of the BROS property and to the southeast. Based on review of the logs of wells installed in and around the BROS site, the confining layer is not present to the northwest of the BROS property. The investigations performed at the CLTL site to the west identified the confining layer on the central and eastern

portion of that site, but it was absent to the west (USEPA, 1990a) Where present, the confining unit ranges in thickness between 8 and 20 feet below the BROS property and thickens downdip to 70 feet in MW-16B (CH_2M Hill, 1996a). Shelby tubes collected from the confining layer had a geometric mean vertical hydraulic conductivity value of 0.00025 feet per day (CH_2M Hill, 1996a). Phase 2 RI activities will provide additional information relative to the extent of the confining layer.

2.4.4.5 Lower Middle PRM

The Lower Middle PRM is a confined aquifer. The low vertical conductivity of the red-grey silty clay confining unit and the marked differences in ion chemistry of the Lower Middle PRM relative to the Upper Middle PRM suggest that ground water flow between the two units is negligible (CH_2M Hill, 1996a). Further, the Lower Middle PRM exhibits an upward vertical gradient in relation to the Upper Middle PRM at several locations.

The Lower Middle PRM ranges in thickness from 15 to 25 feet and consists of a finer sand with a higher concentration of silt and interstitial clay relative to the overlying aquifers. Consistent with the higher percentage of fine sediments, the aquifer has the lowest mean hydraulic conductivity of the three aquifers tested during RI activities for the BROS site. The geometric mean of hydraulic conductivity of the Lower Middle PRM was calculated to be between 10.5 to 15.1 feet per day (CH_2M Hill, 1991a). The Lower Middle PRM also exhibits the lowest hydraulic gradient of the three aquifer units studied ranging from 0.00043 feet/foot to 0.000016 feet/foot. Partially related to low hydraulic conductivity, ground water flow in the Lower Middle PRM is relatively tide dependent and small changes in water-level elevations caused by loading and unloading of the tidal wedge significantly influence ground water flow directions in the aquifer.

Both sands and clays contain significant concentrations of lignitized plant material and exhibit a medium- to dark-grey color common in reduced environments. The hydrochemical facies in the Lower Middle PRM suggests that the aquifer contains a more aged, mature ground water with a higher residence time than the overlying aquifers (CH_2M Hill, 1996a).

2.4.4.6 Confining Layer Between Lower Middle PRM and Lower PRM

A continuous confining layer, consisting of a light grey stiff clay, separates the Lower Middle PRM and Lower PRM aquifers (Kozinski, 1990). The confining unit ranges in thickness between seven feet in Boring S-12, located to the north of the BROS property, to 65 feet in boring MW-16B (CH_2M Hill, 1991). This downdip increase in thickness of the confining layer is consistent with the observations by Zapecza (1984).

2.4.4.7 Lower PRM

The lower PRM is a confined aquifer which lies unconformably over the Wissahickon Formation, the bedrock basement beneath the coastal plain sediments in southwestern New Jersey (Zapecza, 1984). The Lower PRM consists of light grey silts and clays. No monitoring wells have been installed or geotechnical samples have been collected from the Lower PRM during the previous investigations associated with the BROS site or the neighboring CLTL site.

2.5 Environmental Conditions and Summary of Existing Data

Past activities at the BROS property have affected various media at the BROS site. The distribution of site-related chemicals in different media have been investigated as part of the previous studies by USEPA contractors. A conceptual contaminant transport model based on conditions prior to the conclusion of the lagoon work has been developed based on the available data (Figure 4 and 17). Completion of a conceptual contaminant transport model for the present conditions at the BROS property and the surrounding areas will be completed during the Phase 2 RI. An overview of the site conditions based on historical data is presented below.

The environmental conditions discussed in the following sections were distilled from the substantial volume of data collected at the site. Nearly all of this information was collected prior to the conclusion of the lagoon work, and current site conditions reflective of these source removal efforts have not been established. The analytical results for various media have been summarized and compared to the initial preliminary remedial goals (Section 3.2). Various figures have been created to illustrate site conditions and convey the distributions and gradients of

representative COPCs to facilitate the identification of Phase 2 RI/FS data needs. In general, the primary COPCs associated with human health and ecological risk are BETX compounds, PCBs, lead and TPH. Where other COPCs were detected in significant concentrations, or where these COPCs modify the understanding of contaminant distribution and gradients, they are discussed. A detailed list of COPCs and indicator chemicals will be developed for the site and various portions of the site during the Phase 2 RI/FS.

Based on the information on the source areas on the BROS property, pesticides are not site-related COPCs. Pesticides were not identified as a constituent of concern for the waste materials generated during removal and disposal of the contents of the tanks and associated process vessels. In addition, pesticides were not a constituent identified during the removal and incineration of the lagoon residuals. Pesticides have not been identified in the ground water at the BROS property above the NJDEP Ground Water Quality Criteria (GWQC) (N.J.A.C. 7:9-6).

The low concentrations of pesticides detected in the surface water samples, from both Little Timber Creek and Gaventa Pond, and the sediment samples from Little Timber Creek wetlands are likely related to the extensive pesticide use on the adjacent peach orchard, immediately to the west of the BROS property, agricultural activities upstream, to the south in the Little Timber Creek watershed, and aerial spraying of pesticides throughout the area for mosquito control and agricultural uses. Further supporting the conclusion that pesticides are completely attributable to other sources is: information obtained from nearby farmers during the access agreement process; and the presence of the highest pesticide concentrations in the most upgradient surface water sample collected from Little Timber Creek (LTC-05 from south of Route I-295), in upgradient monitoring wells MW-14A, MW-14B, MW-15B, MW-16A, and MW-16B where no site-related COPCs were detected. These wells are in close proximity to agricultural fields. Because pesticides are not a COPC for the BROS property, they will not be discussed in more detail in the sections below nor will further investigation be performed for their presence during the Phase 2 RI, except with respect to the presence of pesticides from off-site sources in samples collected for sediment toxicity studies.

2.5.1 Sources (Primary and Secondary)

2.5.1.1 Primary Sources

The primary historical sources of contamination at the BROS property included a tank farm with over 100 tanks and process vessels, drums, and an approximately 13-acre lagoon (CH_2M Hill, 1996a). All primary sources were removed in the 1980's and early 1990's. The predominant constituents of potential concern from the primary source areas are petroleum hydrocarbons, VOCs (including aromatic and chlorinated compounds), lead and PCBs.

There have been several remedial actions performed at the BROS property to address the primary sources including removal of the tanks and drums as well as demolition and removal of site buildings and miscellaneous site debris. Approximately 400,000 gallons of oils and sludges contained within the tanks and process vessels was disposed off-site (USEPA, 1996a). During the lagoon cleanup over 172,000 tons of material including lagoon sediments, sludges and oil were removed and incinerated. The deepest part of the excavation in the former lagoon was reportedly 19.9 feet below mean sea level (EBASCO, 1995) which is now approximately 30 feet below land surface. The primary sources that remain or may remain include the lagoon residuals that were not removed during the lagoon work, possible underground piping in the former Process and Storage Area, and any buried drums that may remain in the fill material.

Soil and soft bottom sediment samples were collected from the base of the former lagoon during excavation work (CH_2M Hill, 1996a). The testing data is contained in the lagoon sampling memorandum prepared by CH_2M Hill dated January 29, 1996 entitled *Bridgeport Rental and Oil Services Lagoon Sediment Sampling Results*, and additional related data was kept on-site during the cleanup by the Army Corps of Engineers. Post-excavation samples were collected from the bottom of the lagoon after all visibly contaminated material was removed from the area. The results were evaluated by the USEPA to determine if cleanup goals were met. In many instances, additional lagoon material was removed and subsequent sampling was performed. In virtually all instances, with the exception of a very few deep excavation areas well below the water table, the remedial cleanup goals were met. (Don Lynch, personal communication, USEPA; April 1997).

The post excavation samples were analyzed for benzene, toluene, xylenes, lead, zinc, and PCBs. A small number of samples were analyzed for Target Compound List (TCL) VOCs and polynuclear aromatic hydrocarbons (PAHs). Many of the soil/sediment samples were analyzed for BTU content for potential treatment in the USEPA's on-site incinerator which was used as part of the Phase 1 Remedial Action.

Volatile organic compounds (VOCs) detected included vinyl chloride, TCE, and PCE. With the exception of benzene, toluene and xylenes, while the concentrations of individual VOCs were typically below 1 milligram per kilogram (mg/kg) with concentrations mostly below 0.1 mg/kg where analyzed (CH_2M Hill, 1996b). Benzene, toluene and xylene concentrations detected in the samples averaged 1.3 mg/kg, 8.7 mg/kg, and 11.7 mg/kg, respectively. The concentrations of lead and zinc detected averaged 1,079 mg/kg and 133 mg/kg, respectively. PCB concentrations detected averaged 8.7 mg/kg. In several of the soil samples, a variety of PAHs were detected at concentrations between 1 and 6 mg/kg including acenaphthene, acenaphthalene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)/(k)fluoranthene, chrysene, fluoranthene, fluorene, phenanthrene, and pyrene (CH_2M Hill, 1996b).

The soft bottom sediment samples were collected by USEPA contractors from the former lagoon during Phase 1 Remedial Action to confirm that the excavation activities had removed media containing benzene, toluene, ethylbenzene, and xylenes (BTEX) in excess of 10 mg/kg and PCB concentrations in excess of 10 mg/kg. The USEPA has stated that, with a few exceptions(areas requiring deep excavation well below the water table), the lagoon remedial action achieved the cleanup goals established by the USEPA (Don Lynch, personal communication, USEPA; April 1997). Because the post-excavation samples were taken only two feet below the final excavation, concentrations of constituents of potential concern (COPCs) may remain below the sampling locations in the base of the former lagoon. In a few areas, the depth of excavation, which was well below the water table, was limited by the types of equipment used by the contractors. In addition, a mud wave resulted from the pressure of overlying backfill and equipment, forcing peat material and sediments in front of the backfilling operation after the

excavation. The mud wave consists predominantly of peat and fine grained materials that were present near the base of the lagoon within the saturated zone. The proposed Phase 2 RI activities in the vicinity of the former lagoon will be performed to determine the concentrations of the residual source material remaining on the BROS property.

Soil borings were completed in the former Process and Tank Area during the winter of 1996/97 by the USEPA as part of their Phase 3 soil investigation (USEPA, 1998). Soil borings were reportedly completed to evaluate the potential presence of buried drums or debris based on a geophysical survey performed by USEPA contractors and to assess the extent of fingers and veins[1] in the former Process Area and along the southern and eastern fringes of the former lagoon (meeting with USEPA, December 1996). A total of 36 soil borings (Figure 9) were completed to depths between 25.5 and 30 feet below ground surface (BGS). Further, 72 additional soil borings were completed to depths between 6 and 10 feet BGS. The USEPA collected 75 subsurface soil samples from the soil borings which were analyzed for BTEX, PCBs and lead. Three soil samples were analyzed for TCL VOCs, SVOCs, pesticides and PCBs and TAL metals. Nine of the samples were analyzed for toxic characteristic leaching procedure (TCLP) parameters. In addition, 22 Gore-Sorber® screening modules were installed and tested to assess VOC concentrations in soils. Sixty-three soil borings were completed using a cone penetrometer during which tip resistance was measured to evaluate differences in resistance between the various types of strata (e.g., clay and sand). Also, a Rapid Optical Screening Tool (ROST) was used to measure infrared fluorescence intensity of petroleum constituents. As of this writing, the narrative associated with the ROST evaluation and laboratory results of the sampling effort have not been supplied to the BROS Technical Committee.

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[1] As defined in the BROS Consent Decree, "fingers and veins" are areas that contain buried drums, debris, or soils contaminated with hazardous substances, and that (i) are or were contiguous to the lagoon or processing or storage facilities formerly located at the site as documented by historical aerial photography or other evidence and (ii) are located within the lagoon area footprint but outside the previously excavated area.

Benzene concentrations measured during the Phase 3 work ranged from not detected to 18 mg/kg (boring B-18 [Figure 9] at 8 to 9.5 feet BGS). Eight soil samples contained benzene at concentrations that exceeded the preliminary remedial goal (PRG) of 1 mg/kg (The development of PRGs, which are being used as a frame of reference for the analysis of historical data, is described in Section 3.2.). In the 42 out of 78 soil samples where benzene was detected, the average concentration of benzene was 2.1 mg/kg. All of the samples with concentrations which exceeded the 1.0 mg/kg PRG were from the depth interval between 4 and 10 feet BGS and were located to the northwest of the former lagoon along the southern end of the Pepper Building or to the south of the present location of the office trailers (Figure 9).

Toluene concentrations ranged from not detected to 200 mg/kg (boring B-18 [Figure 9] at 8 to 9.5 feet BGS). In the 49 out of 78 soil samples where toluene was detected, the average concentration was 14 mg/kg. No soil sample contained toluene in concentrations that exceeded the PRG of 500 mg/kg.

Ethylbenzene concentrations ranged from not detected to 200 mg/kg. In the 56 out of 78 soil samples where ethylbenzene was detected, the average concentration was 3.3 mg/kg. Only the soil sample with the highest concentration, S45Y-1 from a depth of 8 to 10 feet BGS, located along the northern edge of the former lagoon (Figure 9), exceeded the PRG of 100 mg/kg.

Total xylenes were the most common BTEX constituent found and ranged in concentration between not detected and 1,240 mg/kg (boring B-19 [Figure 9] at 6 to 8 feet BGS). In the 60 out of 78 soil samples where toluene was detected, the average concentration was 33 mg/kg. Thirteen soil samples had concentrations of total xylenes which exceeded the PRG of 10 mg/kg. The distribution of the total xylenes was similar to that of benzene. The highest concentrations of total xylenes were detected between 4 and 13 feet BGS and were located immediately to the north of the former lagoon.

PCB detections were widespread around the former lagoon and in the former process area. PCBs concentrations ranged from not detected to 76 mg/kg (boring B-8 of 8.7 to 10 feet BGS). In the 54 out of 78 soil samples where PCBs were detected, the average concentration was 10 mg/kg. Thirty-nine of the soil samples had concentrations of PCBs which exceeded the PRG of 2 mg/kg. The individual PCB Arochlors detected were 1248 and 1260 with 1260 being the predominant Arochlor in terms of frequency and concentration. In the borings where soil samples were collected from each of the three sampling zones (0 to 10, 11 to 20, and 21 to 30 feet below ground surface) the samples from the shallowest zone (0 to 10 feet) had the highest concentrations of PCBs.

Lead concentrations detected in the soil samples ranged between not detected and 7,890 mg/kg (boring B-17 at 2 to 4.5 feet BGS). Six out of 78 soil samples exceeded the PRG of 600 mg/kg and the average lead concentration in samples where lead was detected was 183 mg/kg. The elevated lead concentrations were detected between 4 and 13 feet BGS off the northwest corner of the former lagoon.

As previously stated, only three soil samples were analyzed for the full TCL and TAL list of parameters. All three samples were collected from borings along the northern edge of the BROS property from depths ranging between 4 and 8 feet BGS. This area is north of where the highest concentrations of VOCs were detected in the former Process Area. Aromatic hydrocarbons and phthalates were detected in two of the three soil samples. Only two compounds were detected at concentrations which exceed the NJDEP SCC. Xylenes at an estimated concentration of 118 mg/kg (versus a PRG of 10 mg/kg) and butyl benzyl phthalate at 130 mg/kg (versus a PRG of 100 mg/kg) were detected in the same sample, S530-1; however, xylenes were detected at 17 mg/kg and butyl benzyl phthalate was not detected in the duplicate sample. Several polynuclear aromatic hydrocarbons (PAHs) were detected as were numerous unidentified compounds in the library searches in both the VOC and SVOC scans, many of which were unknown alkanes and aromatics which would be consistent with degraded petroleum constituents. No chlorinated VOCs were detected in the three soil samples analyzed for VOCs other than BTEX compounds.

None of the nine soil samples analyzed for full TCLP parameters had reported concentrations of constituents exceeding the standards for RCRA characteristics for hazardous waste. The soil boring from which the sample which had the highest concentration of lead (B-17 from 2 to 4.5 feet BGS) had a sample analyzed for TCLP from the next interval (4.5 to 6.3 feet BGS) and lead was detected at 2 mg/ℓ, which is below the RCRA characteristic for hazardous waste of 5 mg/ℓ.

A comparison of the analyses of the Gore-Sorber® data and the soil sampling results was performed, but the results were inconclusive. The lack of a discernible correlation is due primarily to the limited suite of VOC constituents targeted in the laboratory analysis of soil samples (as compared to the analytical parameters targeted for the Gore-Sorbers) and the different depth intervals targeted by the investigative methods. The Gore-Sorbers were installed in unsaturated soils to detect volatile constituents in the vapor phase within the unsaturated zone or partitioning from the vadose zone. In general, Phase 3 soil samples were collected from deeper intervals than those targeted by the Gore-Sorbers.

Observations made by Roux Associates, Inc., representing the BROS Technical Committee, during a portion of the soil boring investigation indicate that no drums were encountered during at least part of the investigation. However, the assessment method (auger drilling) probably could not have identified buried drums, if present.

2.5.1.2 Secondary Sources

The secondary sources associated with the historical activities performed at the BROS property include nonaqueous phase liquid (NAPL), contaminated soils, and sediment and the backfilled lagoon materials.

NAPL

NAPL refers to hydrocarbon compounds or hydrocarbon compound mixtures that are lighter or heavier than water with relatively low water solubility (USEPA, 1991g). Based upon their relative density when compared with water, NAPL can be characterized as light nonaqueous

liquid (LNAPL) or dense nonaqueous liquid (DNAPL). LNAPL and DNAPL are discussed in the following paragraphs.

LNAPL

LNAPL has been identified in several areas on and surrounding the BROS property (Figure 8):

- along the southwest and east sides of the Pepper building;
- along the drainage swale along Route 130 (MW-13A);
- east of the former lagoon (MW-1A, S-11A);
- south and southeast of the former lagoon (Phase 3 soil borings S9W-2, S11AA-2 and S11AA-4);
- along the northern edge of the former lagoon (Phase 3 soil borings B-21, B-36 and B49W-1);
- near the office trailers (Phase 3 soil borings B-9 and R39I-1); and
- in the area of Common Reed (*Phragmites*) in the wetlands adjacent to the BROS property just north of U.S Route 130.

Floating oil on top of the former lagoon was characterized through the analysis of ten samples (USACOE, 1986) and primarily contained non-aromatic hydrocarbons with only between 1 and 35 mg/ℓ of BTEX compounds. Chlorinated solvents were detected, but were present at concentrations below the 1 mg/ℓ detection limit. Various individual phthalates and PAHs were detected at concentrations between 10 and 500 mg/ℓ. PCBs were detected between 360 and 710 mg/ℓ. The distribution and characteristics of the LNAPL on and adjacent to the BROS property will be evaluated in the Phase 2 RI.

To date, the only investigation performed specific to LNAPL outside of the lagoon is a bail-down test performed in a monitoring well by a USEPA contractor (Murdock, 1997). This well is located near the Pepper Building (Don Lynch, USEPA, April 1997). The apparent thickness of LNAPL in the well identified as "USGS" in the report was 2.98 feet. The bail-down test indicated an actual thickness of 0.6 feet. The actual designation of the well was not identified and the chemical characteristics of the LNAPL were not evaluated.

Although it is documented that LNAPL is present in several areas of the BROS property in the form of LNAPL above and on top of the water table (e.g., MW-1A, MW-13A, and S-11A), it is also known that some LNAPL is present as residual product trapped below the water table (e.g., Phase 3 Borings 21 and 36). Residual product is defined by the NJDEP as a "separate-phase material present in concentrations below a contaminant's residual saturation point, retained in soil or geologic matrix pore spaces or fractures by capillary forces" (N.J.A.C. 7:26E-1.8). Petroleum-related floating product present on the surface of the former lagoon was trapped in soils below the water table when the surface of the lagoon was lowered during de-watering and excavation. Chemical analysis of the residual product and visually stained soils below the water table has not been completed. Activities proposed in the Phase 2 RI will be targeted to evaluate the quantity, distribution, characteristics, remediation, and recoverability of the residual product on the BROS property.

DNAPL

DNAPLs are chemical compounds that are heavier than water in their pure phase (USEPA, 1993f). In order for hydrocarbon liquids to form a separate phase in the soil/aquifer matrix the DNAPL components (dense hydrocarbons) must have been discharged, and must remain at concentrations that exceed their solubility limit. DNAPL will not be formed in the environment from dissolved-phase or dispersed sources. Rather, a significant DNAPL source of ground water contamination can only exist in the soil/aquifer matrix as a result of the discharge of a large volume (greater than 200 gallons) separate-phased source into the saturated or unsaturated zone (Cherry, 1998).

DNAPL exists in the soil/aquifer matrix as free-phase DNAPL or as residual DNAPL. Free-phase DNAPL is the separate-phased liquid existing in the subsurface with a positive pressure such that it can flow vertically through an aquifer or laterally down the slope of low-permeability units. Residual DNAPL is held in soil pore spaces or fractures by capillary forces (negative pressure) and tends to remain trapped within the pores where it can be a source of dissolved-phase ground water contamination. In saturated soils, the amount of residual, or trapped, DNAPL normally ranges between 15% and 50% of the soil pore volume (USEPA, 1993f). Total hydrocarbon concentrations in excess of 10,000 mg/kg are typically characteristic of residual DNAPL (Cherry, 1998).

When a sufficient mass of separate-phased DNAPL is released to the environment, it will move vertically downward through the unsaturated and saturated zones under the force of gravity. Soil capillary action draws in all directions resulting in residual NAPL wherever free product moves through. The DNAPL will continue downward until the free-phase DNAPL is exhausted and trapped as residual DNAPL. Where fine texture (silts and clays) and lower permeability units are present, free-phase DNAPL will pool and will wick into the fine texture (clay, silt) unit by capillary forces. Finally, when the thickness of the perched free-phase DNAPL pool becomes great enough to overcome the capillary forces retarding gravitational movement, the free-phase DNAPL can move laterally down the slope of low-permeability units. As it moves, free-phase DNAPL will continue to become trapped as residual DNAPL. Where the low-permeability units are lenticular and sufficient free-phase DNAPL exists, the free-phase DNAPL can spill over the edge of the low-permeability lens and continue to migrate vertically; all the while becoming trapped as residual DNAPL and dissolving into aqueous form based on its solubility limit at the temperature of the ground water..

No DNAPL is suspected at the BROS site, based upon a consideration of the historical waste management processes used at the site, the results of previous investigations and the physical/chemical properties of DNAPL as they behave in the environment. The waste oil processing operations that were previously conducted at the BROS facility involved the removal

of solids, water and water-soluble materials from the oil. As such, waste materials generated from the process, and released at the site, were predominantly aqueous phase materials that would not be dense enough to be classified as a DNAPL. As a consequence of the contact between the aqueous and organic phases during the oil recovery process, the water soluble components of the waste oil were dissolved in a concentrated aqueous solution. Therefore, it is not surprising that solvent concentrations in soils and ground water are relatively high.

As detailed in Section 2.5.1.1, historical soil sampling of soft bottom sediments and soils, solvent concentrations were considerably below 1,000 mg/kg and chlorinated solvents concentrations were typically below 1 mg/kg. These results emphasize the relatively low concentrations of the types of hydrocarbons that are known to form DNAPLs. Moreover the USEPA Phase 3 investigative strategy involved the analysis of only three of 78 soil samples for TCL-VOCs. This strategy was not consistent with the historical ground water data which detected elevated concentrations of chlorinated solvents.

Even if some chlorinated solvents were brought to the site in pure form, due to their greater affinity for hydrocarbons (oil) than water, they would have dissolved and dispersed in the oil matrix during the processing operations. As this oil matrix is less dense than water, chlorinated solvents would no longer exist in a separate-phase form capable of creating a DNAPL release mechanism. The chlorinated solvents can not recombine or reconcentrate to form a concentrated matrix.

Based upon the concentrations of TCE detected in well S-11C, CH_2M Hill monitored for the presence of DNAPL in monitoring wells proximate to S-11C (MW-5B, S-11C, and MW-11B). The assessment involved the collection of ground water samples with a clear plastic bailer and visual observations for DNAPL. Further, DNAPLs were not reported during the 1990 and 1993 ground water sampling events conducted by CH_2M Hill. Concentrations of VOCs reported in CH_2M Hill (1996a) suggest that DNAPL is not present at the BROS site. Based upon these

findings and conclusions, no additional investigations were proposed or suggested by CH_2M Hill for DNAPL evaluation.

As a function of DNAPL's tendency to become trapped in soil pore spaces or fractures by capillary forces, a relatively large volume of dense separate-phase source would be required to generate free-phase DNAPL at the BROS site, especially in the Upper Middle PRM which is 40 to 60 feet from the surface. As discussed previously, it is unlikely that such a dense separate-phase source existed given the types of chemical processes used for waste oil recovery. The following calculation provides an estimate of the volume of free-phase solvent that would need to be released to begin to form a pool of free-phase DNAPL at the BROS site. This estimate provides a frame of reference for considering the sizable amount of separate-phase source necessary to begin to form a pool of free-phase DNAPL at the BROS site. The calculation is based upon an estimate of the quantity of DNAPL that would be retained in the soil pores as the source moves downward through the soil column as determined by the following equation.

Gallons of residual DNAPL trapped in the soil pores	=	Volume of soil column (cubic feet)	x	Porosity of unit	x	Residual saturation of DNAPL	x	7.48 gallons per cubic ft

The volume of the soil column is calculated as:

$$V=\pi r^2 h$$

Where:

V is the volume of the cylinder;

r is the radius of the circle; and

h is the height of the cylinder.

The calculations were completed using 40 feet for thickness between land surface and the base of the Upper PRM and 80 feet for the distance between the base of the former lagoon and the base of the Upper Middle PRM. Representative values were used for the aquifer porosity and residual saturation based upon site-specific data and the typical ranges for these parameters. CH_2M Hill

(1996a) had previously used a porosity range of 0.22 to 0.35 for both the Upper PRM and the Upper Middle PRM and the midpoint of this range (0.285) was used in the calculation. The midpoint of the residual saturation range for saturated soils (32.5%) was used.

Using a five foot radius for the soil column, the quantity of separate-phase DNAPL source required to begin to form a pool of free DNAPL at the base of the Upper PRM and the base of the Upper Middle PRM was calculated. For the Upper PRM, approximately 2,200 gallons of pure solvent must be released. For the Upper Middle PRM, approximately 4,400 gallons of pure solvent must be released from the surface. The release scenarios could be variable, but the point of these calculations is to illustrate that substantial volumes of free product (pure chemical) are required to cause a significant DNAPL problem at the BROS Site.

Although DNAPL is not expected, investigative activities to detect DNAPL have been incorporated into the Work Plan. These investigations are focused to the places where DNAPL would pool, where it would wick into low-permeability units and where it would leave residual DNAPL.

Soils

Based upon the results of the prior investigations, soils in the former Process Area exhibit staining, organic vapor concentrations and some layers of residual free product indicative of non-chlorinated petroleum hydrocarbons. Gore-Sorber® screening indicates the potential presence of chlorinated VOCs, although a more detailed comparison of Gore-Sorber® results with soil data is inconclusive (Section 2.5.1.1). Additional data collection activities are planned to more fully characterize the distribution and probable fate of the COPCs in site soils.

Sediments

When the eastern dike of the lagoon was breached in June 1972, liquids from the lagoon, including some LNAPL, entered the Little Timber Creek Swamp. Sediments within Little Timber

Creek Swamp contain LNAPL, PCBs, PAHs and metals associated with the lagoon release. The sediments potentially serve as a source of these constituents to surface water and ground water.

Lagoon Ash and Fill

During the lagoon work, imported backfill and stabilized ash were placed in the former lagoon. The incinerator ash was stabilized with lime to impede the leaching of residual metals. The design objective was to place fill material to an elevation above the water table, followed by the incinerator ash, but this may not have been accomplished at all locations. Further, the permeability of the fill material is not known, although it is in direct communication with the Upper PRM aquifer. Phase 2 RI/FS data gaps include an estimation of the permeability of the fill, evaluation of the depth of ash relative to current ground water elevations and an assessment of the potential impact of residual lime on ground water quality, especially if it discharges to the naturally acidic surface water of Little Timber Creek Swamp.

2.5.2 Soil

Throughout this Work Plan, the term soil will be used for non-hydric soils and the term sediment will be used to describe materials covered by water at least 50% of the growing season (April to mid-September), as requested by USEPA in the second scoping meeting. Between these zones where there are hydric soils which are not inundated most of the growing season, site-specific screening concentrations and goals will be established based upon site-specific conditions relevant to the risk assessment, rather than using soil or sediment screening criteria.

Three soil investigations were previously completed as part of the Phase 2 RI/FS. As previously discussed in Section 2.5.1, the USEPA completed a soil boring program in the former Process Area and surrounding the former lagoon. Visual inspection of many of the soil borings indicated stained soils and possible residual LNAPL. The contaminants detected were limited to BTEX, PCBs and Lead. However, the laboratory analysis included only three sample analyses for chlorinated VOCs. CH_2M Hill completed limited surface soil sampling activities in three areas

around the BROS property (Figure 9). In addition, subsurface soil samples were collected during the installation of monitoring wells MW-1 through MW-13 by CH_2M Hill in 1990.

CH_2M Hill collected surface soil samples from three areas surrounding the perimeter of the former lagoon: Area 1 to the northeast, Area 2 to the east, and Area 3 to the south (Figure 9) (CH_2M Hill, 1991b). Area 1 was located to the northeast of the lagoon and reportedly was an area of obvious visual contamination (CH_2M Hill, 1991b). The surface soil sampling in Area 1 was conducted after the USACOE had completed the excavation of soil. Six post-excavation soil samples were collected from Area 1 from a depth of zero to one foot BGS. The soil samples were analyzed for TCL VOCs, TCL SVOCs, PCBs, pesticides and TAL metals. No VOCs were detected at concentrations exceeding the PRGs (Section 3.2). Four PAHs were detected at concentrations greater than the PRG in one or more sample: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene. Benzo(a)anthracene exceeded the PRG of 0.9 mg/kg in three of the six samples analyzed with 2 mg/kg the highest concentration detected and an average concentration of 1.43 mg/kg. Five of the six samples analyzed exceeded the PRG for benzo(a)pyrene (0.66 mg/kg) with 4.1 mg/kg the highest concentration detected and an average of 1.87 mg/kg. Benzo(b)fluoranthene was detected in three samples exceeding the PRG (0.9 mg/kg) with the highest concentration of 2.4 mg/kg and an average of 1.05 mg/kg. Two of the six soil samples exceeded the PRG for benzo(k)fluoranthene (0.9 mg/kg) with the highest concentration of 1.5 mg/kg and an average of 0.82 mg/kg.

PCBs were detected in five of the six surface soil samples from Area 1 at concentrations exceeding the PRG of 0.49 mg/kg. The highest concentration detected was 59 mg/kg with an average of 12 mg/kg. Two metals, lead and cadmium, were detected at concentrations exceeding the PRGs; 600 mg/kg and 1 mg/kg, respectively. Lead was detected in one sample exceeding the PRG at 3,980 mg/kg with an average of 915 mg/kg. Cadmium concentrations exceeded the PRGs in three samples with the highest concentration at 8 mg/kg and an average of 3 mg/kg.

The surface soil samples from Areas 2 and 3 were analyzed for TCL VOCs, TCL SVOCs, PCBs, pesticides and TAL metals. In Areas 2 and 3, no VOCs were detected in the soil samples collected. Only two samples from Area 2, LTC-03 and LTC-07, had estimated concentrations of PAHs which exceeded the PRGs. These two samples were closest to the wetlands area and may represent remnants of the residual material deposited in the low areas to the east of the lagoon from the lagoon overflow events. In each instance sample LTC-03 had the highest concentration of PAHs: 2.9 mg/kg of benzo(a)anthracene (PRG of 0.9 mg/kg); 2.2 mg/kg of benzo(a)pyrene (PRG of 0.66 mg/kg); 2.3 mg/kg of benzo(b)fluoranthene (PRG of 0.9 mg/kg); and 1.7 mg/kg of benzo(k)fluoranthene (PRG of 0.9 mg/kg). The average concentrations of each of the PAHs [0.81 mg/kg of benzo(a)anthracene, 0.58 mg/kg of benzo(a)pyrene, 0.67 mg/kg of benzo(b)fluoranthene, and 0.57 mg/kg of benzo(k)fluoranthene] was below their respective PRG. Sample LTC-03 was the only sample in Area 2 which had concentrations of cadmium (3.7 mg/kg) and lead (22,000 mg/kg) which exceeded the PRGs (1 mg/kg and 600 mg/kg, respectively). No elevated concentrations of SVOCs were detected in the samples from Area 3 when compared to the PRGs. No PCBs were detected in Area 2 at concentrations which exceeded the PRGs. No PCBs were detected in Area 3. No metals were detected at concentrations exceeding the PRGs in Area 3.

In support of the lagoon work and incineration project, the USEPA and USACOE placed fill material over portions of the former Process Area, especially in areas where soil and ash management were conducted. Fill material was placed before the incineration work began to prepare and grade these management areas. During the incinerator decommissioning, additional fill material was emplaced and stabilized with grass seed. The origin and source of this fill material was not recorded in the reports produced by the USEPA or the USACOE. The Phase 2 RI/FS will include an evaluation of surface soil quality, including an evaluation of the fill materials emplaced in the former Process and Tank Areas.

Subsurface soil samples were collected during the installation of the monitoring wells (individual and clustered monitoring wells designated MW-1 through MW-13) installed by CH_2M Hill in

1990. Most of the soil samples were collected below the water table in discrete zones which were targeted for sampling based on their location (e.g., base of Upper Middle PRM) or a zone which exhibited visual staining or elevated PID readings (CH_2M Hill, 1991b, 1996a). The subsurface soil samples were analyzed for TCL VOCs, TCL SVOCs, pesticides, PCBs, TPH, TOC and TAL metals.

With the exception of one subsurface soil sample, MW-1C, none of the soil samples had concentrations of VOCs exceeding the PRGs. The sample was collected from the top of the intermittent clay (20 to 22 feet BGS), and contained benzene and trichloroethylene at concentrations slightly greater than the PRGs. In the same soil sample, several PAHs [benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, benzo(a)anthracene, fluoranthene, etc.] were detected at concentrations above the PRGs. With the exception of benzo(a) anthracene compound detected slightly above the PRGs in the soil sample collected at the water table from MW-1C (4 to 6 feet), no other subsurface soil samples exceeded the PRGs. No PCBs or metals, with the exception of cadmium, were detected at concentrations exceeding the PRGs. It is anticipated that the cadmium concentrations detected at depth may not be related activities from the BROS property, but may be naturally occurring as it only slightly exceeded the PRGs. Numerous unidentified petroleum hydrocarbons were detected in the SVOC library search in two soil samples from MW-1C (4 to 6 feet and 106 and 108 feet) which indicate that the compounds found in the soil samples from MW-1C are related to the petroleum products found in the former lagoon. Only one soil sample MW-1C (20 to 22 feet) had an estimated concentration of TPH (24,112 mg/kg) which exceeded the PRG of 10,000 mg/kg. The high concentrations of TPH are a result of the petroleum residuals which were placed in the BROS lagoon or related to several small lagoon-type structures in the area which were observed in the aerial photographs from 1963 through 1974 (ERI, 1993).

2.5.3 Air

Ambient air quality monitoring was performed on and in the vicinity of the BROS property during the lagoon work by Ebasco (1995). The air monitoring stations in the vicinity of the BROS

property was determined by Ebasco based on the results of air transport modeling and included locations near the BROS property.

The air monitoring was performed during the time of highest potential discharge of COPCs to the atmosphere as it was performed during the excavation and on-site incineration of the lagoon residuals and treatment of recovered ground water. The air was sampled for PCBs, TSP, particulates (PM_{10}) and metals, including mercury. All of the air monitoring results were below the National and New Jersey Ambient Air Standards.

Since the amount of intrusive activities to be performed at and in the vicinity of the BROS site will create significantly less of a disturbance to subsurface media than the lagoon work, ambient air quality monitoring is not warranted during the Phase 2 investigation. The HASCP details procedures and action levels for the implementation of monitoring and engineering controls based upon organic vapor concentrations detected during the Phase 2 investigation, as part of the health and safety program.

2.5.4 Ground Water Quality

As previously discussed in Section 2.4.4, three aquifer systems have been recognized in the vicinity of the site including the Upper PRM, the confining layer between the Upper PRM and the Upper Middle PRM, the Upper Middle PRM, the confining layer between the Upper Middle PRM and the Lower Middle PRM, and the Lower Middle PRM (Figure 4). In 1990 and 1993, ground water samples were collected from monitoring wells installed in each of the three aquifers. Ground-water sampling results for the monitoring wells are outlined below with reference to the PRGs (Section 3.2).

2.5.4.1 Upper PRM

The lateral distribution of the COPCs in ground water in the Upper PRM aquifer, identified primarily by elevated concentrations of BTEX compounds, generally trends to the north-northwest, parallel to the direction of shallow ground water flow in the area (CH_2M Hill, 1996a).

The lateral distribution of COPCs in ground water is likely to extend to the east towards Little Timber Creek Swamp; however, the extent is not defined and will be an objective of the Phase 2 RI. In addition, there were several COPCs detected which may (at least partially) be field or laboratory introduced contaminants [e.g., acetone, methylene chloride and bis(2-ethylhexyl)phthalate]. A representation of COPCs in the Upper PRM was prepared based upon the most recent two rounds of VOC data (CH_2M Hill, 1996a) and data from the adjacent CLTL site (Figure 10).

In 1990, three of the 13 wells sampled (MW-1A, MW-4A and S-2A) contained VOC concentrations in excess of the PRGs (Figure 11). Methylene chloride concentrations in MW-7A and MW-13A exceeded the PRGs, but methylene chloride is most likely a laboratory contaminant. Acetone concentrations were widespread, however, acetone is also a common field or laboratory contaminant; therefore, the presence of acetone will be further evaluated during the Phase 2 RI. With the exception of bis(2-ethylhexyl)phthalate, no concentrations of SVOCs were detected above the PRGs. The bis(2-ethylhexyl)phthalate may be a laboratory contaminant as it was detected at low concentrations in several wells. No PCBs were detected at concentrations exceeding the PRGs. Iron and manganese concentrations in filtered ground water samples exceeded the PRGs in the majority of the wells in 1990. These metals are common constituents found in the Upper PRM aquifer (CH_2M Hill, 1996a).

In 1993, none of the four wells [MW-11A(D), MW-14A, MW-15A and MW-16A] sampled contained exceedances of the PRGs for VOCs or SVOCs. No PCBs were detected. Elevated concentrations of iron and manganese with respect to the PRGs were detected in filtered ground water samples in 1993 and are anticipated to be related to background conditions in the Upper PRM. A cadmium concentration in excess of the PRG was detected in MW-15A during the 1993 sampling event.

Phase 2 RI activities are planned to complete the assessment of the fate, distribution and gradients of COPCs in the Upper PRM aquifer as necessary to support the risk assessment and evaluate

remedial alternatives. Since each monitoring well in the Upper PRM has only been sampled once, and those samples were collected prior to conclusion of the lagoon work, additional sampling rounds from selected wells is necessary to assess the current ground water quality and to determine any trends with respect to movement and attenuation of COPCs. Sampling of selected monitoring wells in the Upper PRM during the Phase 2 RI will evaluate water quality conditions after the conclusion of the lagoon work. In addition, there is no data for the Upper PRM from beneath the Little Timber Creek Swamp to determine whether the COPCs detected in the sediments may be a source to the Upper PRM immediately below it or whether the ground water is discharging COPCs to surface water. The installation of additional monitoring wells within and at the base of the Upper PRM, screened immediately above the confining layer (if present), will be used to evaluate the vertical gradients of COPCs and rates of movement within the aquifer. These data gaps will be addressed by the Phase 2 RI activities.

Confining Layer Between Upper PRM and Upper Middle PRM

If the COPCs from the Former Lagoon and Process Areas have reached the confining layer between the Upper PRM and the Upper Middle PRM, they may act as a continuing source to the overlying and (potentially) underlying aquifers. The lower permeability and transmissivity of this unit will impede restoration efforts, but may cause elevated concentrations in adjacent aquifers as residual constituents diffuse from the confining layer. The physical and chemical characteristics of the confining layer, along with the distribution of COPCs in the layer will be investigated during the Phase 2 RI.

2.5.4.2 Upper Middle PRM

The lateral extent of COPCs in ground water in the Upper Middle PRM aquifer, identified primarily by elevated concentrations of chlorinated VOCs, generally trends to the southeast (CH_2M Hill, 1996a) in the predominant direction of ground water flow. The distribution of the COPCs in the Upper Middle PRM has been compiled (Figure 12).

During the 1990 and 1993 sampling rounds, 12 and 9 monitoring wells, respectively, were sampled (Figure 13). Only four monitoring wells (S-11C, MW-5B, MW-10B and MW-11B) were sampled during both rounds. VOCs were detected in six wells (MW-5B, MW-6B, MW-10B, MW-11B, S-2C and S-3C) at concentrations exceeding the PRGs. All of the monitoring wells which had VOCs which exceed the PRGs were located to the east or southeast of the Former Lagoon in the downgradient direction of ground water flow for the Upper Middle PRM. Benzene and trichloroethylene (TCE) were the COPCs which exceeded the PRGs most frequently. The highest concentrations of VOCs were detected in monitoring well S-11C, which is located immediately adjacent to the eastern side of the former lagoon. During the 1993 sampling round concentrations of VOCs from three of the four monitoring wells (S-11C, MW-5B and MW-11B) also sampled in 1990 went up slightly and concentrations in the fourth well (MW-10B) went down. The overall the concentrations of VOCs were similar in both events except that concentrations of acetone were detected at a significant concentration in S-11C (40,000 $\mu g/\ell$). It is suspected that the acetone, as well as methylene chloride and carbon disulfide, are laboratory contaminants introduced during sampling and decontamination activities.

During both rounds of ground water sampling, with the exception of widespread detections of bis(2-ethylhexyl)phthalate (which is suspected to be a laboratory contaminant) only monitoring well S-11C had detections of SVOCs. Only bis(2-chloroethyl)ether and isophorone were detected at concentrations exceeding the PRGs. The higher concentrations of VOCs and SVOCs detected in S-11C may be related to its location as an area containing several small lagoon-type structures was observed in the aerial photographs from 1963 through 1974 (ERI, 1993). No PCBs were detected at concentrations exceeding the PRGs. As with the Upper PRM, iron and manganese were detected in most of the wells and is a regional constituent in the aquifer.

The downgradient distribution of COPCs in the Upper Middle PRM aquifer has not been fully defined. Although trace concentrations of two BTEX compounds were detected in one sampling round completed in a monitoring well located at the furthest downgradient sampling point to the southeast, MW-14B. CH_2M Hill stated that the source of those compounds were not necessarily

from the former lagoon area (1996a). Additional monitoring wells between the source area and the wells installed by the USEPA along Swedesboro-Paulsboro Road (MW-14B, MW-15B and MW-16B) are proposed in the Phase 2 RI to evaluate the lateral extent of COPCs.

CH_2M Hill (1996a) concluded that the COPCs in the Upper Middle PRM had been transported vertically downward where the semiconfining unit between the Upper PRM and Upper Middle PRM had transitioned from a clay unit to a silt in the vicinity of monitoring well S-11C on the BROS property. The COPCs were then transported in the ground water in the direction of flow in the Upper Middle PRM, to the southeast. The properties and extent of the confining layer below, around and to the east of the former lagoon and former Process Area will be reevaluated in the Phase 2 RI. The installation of the additional monitoring wells in the Upper Middle PRM will include wells screened immediately below the confining layer, if present, and at the base of the Upper Middle PRM to evaluate the vertical gradient of rates of movement COPCs within the aquifer.

Confining Layer Between Upper Middle PRM and Lower Middle PRM

As discussed with the confining layer above the Upper Middle PRM, if COPCs become trapped in the confining layer they may act as a continuing source. Soil samples will be collected from wells installed during the Phase 2 RI to evaluate whether the lower permeability and transmissivity of this unit will impede diffusion and restoration efforts. The physical and chemical characteristics of the confining layer, along with the distribution of COPCs in the layer will be assessed.

2.5.4.3 Lower-Middle PRM

Ground water samples were collected from the Lower Middle PRM in 1990 from four wells (MW-1C, MW-2C, MW-3C and MW-4C). Only tetrachloroethylene (PCE) and benzene concentrations in well MW-4C exceeded the PRGs. No SVOCs, PCBs, pesticides or dissolved metals were detected above the PRGs. CH_2M Hill (1996a) concluded that the Lower Middle PRM does not warrant further investigation because the unit pinches out downdip and becomes

clay rich, and based on a conservative transport model, they concluded no significant migration of COPCs. No additional investigation is proposed for this unit as part of the Phase 2 RI.

2.5.4.4 Lower PRM

Three soil borings were completed into the Lower PRM as part of the previous studies. No monitoring wells have been installed in the Lower PRM. Results of geophysical logs run from within the borings suggest high chloride and total dissolved solids (TDS) concentrations are present within the Lower PRM (CH_2M Hill, 1996a). Brackish surface water intrusion upcoming from downdip portions of the aquifer due to regional overpumping is a probable source of the deteriorated ground water quality in the Lower PRM. CH_2M Hill (1996a) states that the Lower PRM in the vicinity of the BROS site has the following characteristics:

- there is evidence of salt water intrusion into the Lower PRM which would render the ground water in this aquifer unpotable (Zapecza, 1984);
- the confining bed between the Lower Middle PRM and the Lower PRM is continuous and ranges in thickness from seven to 65 feet; and
- the cation/anion chemistry of the Lower Middle PRM is evidence of a mature ground water with a high residence time. These data indicates that leakage between the Upper Middle PRM and Lower Middle PRM is negligible, thereby mitigating the potential for impacts to the Lower PRM from the Upper Middle PRM through the intervening unit.

Accordingly, CH_2M Hill (1996a) concluded that the Lower PRM does not warrant further investigation.

2.5.5 Surface Water Quality

Surface water samples were collected by CH_2M Hill in June, 1990 from Little Timber Creek and Gaventa and Swindell Ponds. The surface water samples were analyzed for TCL VOCs, TCL

SVOCs, pesticides, PCBs, TAL metals, TPH and a number of conventional parameters. The results of the surface water sampling is presented below.

2.5.5.1 Little Timber Creek

CH_2M Hill (1996a) collected five surface water samples from Little Timber Creek (Figure 14). Benzene was the only VOC detected in the sample collected near U.S. Route 130, LTC-01, at a concentration more than the PRG. No SVOCs were detected at concentrations exceeding the PRGs. PCBs were detected in three surface water samples at concentrations exceeding the PRGs with the highest concentration at the sample location LTC-01. Lead was detected in only one sample, LTC-02, at a concentration exceeding the PRG.

The COPCs detected at concentrations greater than the PRGs were the same constituents detected in the wetlands and Little Timber Creek sediments. The downstream distribution and gradients of COPCs in surface water have not been established, nor has the distribution of COPCs in the surface water associated with Little Timber Creek Swamp. The distributions, gradients and likely sources of COPCs will be evaluated as part of the Phase 2 RI activities.

2.5.5.2 Gaventa Pond

CH_2M Hill (1996a) collected three surface water samples from Gaventa Pond when seepage from the former lagoon was still active. One of the three surface water samples was collected within the area contained by an oil boom. The boom has since been removed as no oil seeps remain. No VOCs were detected at concentrations exceeding the PRGs in any of the surface water samples. The VOCs that were detected, carbon disulfide, 2-butanone and 2-hexanone are most likely laboratory or field introduced contaminants. Four different SVOCs were detected in the surface water samples at concentrations below the PRGs. Two of the SVOCs were PAHs (anthracene and pyrene) which were detected only in the surface water sample collected from within the boomed area, GVP-01.

PCBs were only detected from the sample collected from within the boom contaminant area in the northeast corner of Gaventa Pond where a sheen was present. The reported PCB concentrations were 110 µg/ℓ of Aroclor 1260 and 25 µg/ℓ of Aroclor 1016. The solubility of Aroclor 1260 in water is 2.7 µg/ℓ so this sampling result likely represents a laboratory or sampling error, or the collection of floating oil in the water sample (USEPA, 1980). TPH concentrations were detected in two samples at 0.5 mg/ℓ and 18.5 mg/ℓ with the highest concentration detected from the sample within the boomed area. Antimony and lead were the only metals detected at concentrations exceeding the PRGs. Lead was only detected at concentrations exceeding the PRG in the sample from the boomed area. TPH and unknown hydrocarbon TICs from the SVOC analysis were detected in the sample collected from within the boomed area. With the exception of antimony detected exceeding the PRG in sample GVP-03, all of the exceedances of the PRGs were from the sample collected from within the boomed area, GVP-01. It is anticipated that the COPCs that were detected at elevated concentrations in sample GVP-01 represent constituents from the oil sheen and do not represent the water quality of Gaventa Pond. Additional surface water sampling is proposed to evaluate the COPCs in the northeast corner of Gaventa Pond.

Since the completion of lagoon work, visual evidence of seepage is not apparent. Consequently, the available data are no longer representative of site conditions.

2.5.5.3 Swindell Pond

Two surface water samples were collected from Swindell Pond by CH_2M Hill (1996a). No VOCs, SVOCs, PCBs, metals or TPH were detected in the surface water samples above the PRGs. Additional surface water sampling is proposed to confirm the results of the CH_2M Hill data.

2.5.6 Sediment Quality

Soil and/or sediment samples were collected by CH_2M Hill from the Little Timber Creek and associated wetlands and from Gaventa and Swindell Ponds for laboratory analysis of TCL VOCs,

TCL SVOCs, PCBs, pesticides, TAL metals and TPH. As discussed previously, sediment is defined as those materials which are below water 50% of the time during the growing season (late March to late September). The samples collected from below standing water in Little Timber Creek and Gaventa and Swindell Ponds are obviously sediment samples. Due to uncertainty over the actual sampling location, it is unknown which the samples from Little Timber Creek Wetlands were sediment or soil samples. However, for discussion purposes here, the samples are assumed to be from sediments. The sediment samples discussed below were compared to the PRGs as presented in Section 3.2.

Additional information about the environmental setting of conditions in the wetlands and ponds is summarized in the Problem Formulation section of the Ecological Risk Assessment (Task VIB).

2.5.6.1 Little Timber Creek and Swamp

Surface water flow through Little Timber Creek Swamp is diffuse and spread over a large area, with concentrated flow limited to the immediate vicinity of culverts passing under roadways. Since Little Timber Creek does not have a clearly defined channel north of Route 295 and south of Route 44, the creek and the swamp are addressed as one unit. The concentrations of COPCs increase downstream towards Route 130, potentially as a result of transport from the vicinity of the Area 1 excavation and from the LNAPL-containing area evidenced by the abundance of Common Reed (*Phragmites*). The distribution of COPCs in Little Timber Creek sediments in excess of risk-based Remedial Action Objectives (RAOs) has not been determined and will be evaluated as part of the Phase 2 RI.

Five sediment samples were collected from along Little Timber Creek. No VOCs were detected at concentrations exceeding the PRGs. Both acetone and carbon disulfide were detected at low concentrations in a sample, as well as in the blanks, indicating field or laboratory contamination. PAHs were detected in samples LTC-01 and LTC-02 which exceeded the PRGs. The samples also had a large number of tentatively identified compounds including unknown hydrocarbons, consistent with the historical release of hydrocarbons from the lagoon. PCBs were detected in

three samples (LTC-01, LTC-02 and LTC-03) at concentrations exceeding the PRGs. Aroclor 1260 was detected in LTC-01 and LTC-02 and Aroclor 1248 was detected in sample LTC-03. Lead was detected at concentrations which exceed the PRGs in the same three samples as the elevated PCB detections. Several other metals (cadmium, chromium, and zinc) were detected in one or more sample at concentrations which slightly exceed the PRGs. The concentrations of TPH were the highest in LTC-01 and LTC-02 which correspond to the highest concentrations of PAHs.

Three transects of soil borings were collected from the Little Timber Creek Swamp (Figure 14). Based on CH_2M Hill's description of the soil types in the wetlands all of the samples were collected from a black, extremely acidic, granular soil consisting of decomposed organic matter classified as Muck, with the possible exception of sample T3-S7, which may have been collected in the Woodstown and Klej loamy sands (1992).

The results of the limited sediment samples and visual observations from the wetlands provide a basis for the preliminary identification of three primary zones within the wetlands. The highest concentrations of COPCs (including LNAPL) are located in the center of the wetland area to the east and northeast of the former lagoon. This zone is designated the "*de manifestis* zone" and is characterized by the abundance of Common Reed (*Phragmites*) (Suter et al., 1995). Residual product (LNAPL) is present based on visual inspection and the elevated TPH concentrations detected in the sediment samples. This LNAPL may be a continuing source of COPCs in surface water and ground water. As such, it is likely that the *de manifestis* area will be targeted for active restoration and the Phase 2 RI activities will focus on establishing the physical dimensions of this area. It is hypothesized that where LNAPL exists in the wetlands, the physical, chemical and biological mechanisms can not completely sequester or process the COPCs at a significant rate due to the high COPC concentrations. The sampling design will provide for the determination of the vertical extent of COPCs in the *de manifestis* zone.

The zone surrounding the *de manifestis* zone is designated the "intermediate zone." The intermediate zone is characterized by no readily observed change in habitat but possible shifts in plant communities and densities, low probability of widespread residual NAPL in sediments, low probability of COPCs in surface water, capacity of the system to process organic residuals and sequester inorganic constituents and concentrations of COPCs exceeding PRGs. In this zone, COPC processing of organic residuals is ongoing, and the sequestration capacity of inorganics has not been exceeded. The intermediate zone serves an important function in mitigating the movement and potential bioavailability of COPCs to downgradient locations.

The zone surrounding the intermediate zone is the "*de minimis* zone" where COPCs are actively being processed or sequestered and the ecological risks are low. The *de minimis* zone is characterized by no shifts in plant communities, no residual NAPL in sediment, COPCs not detected in surface water, excess capacity of the system to process organic residuals and sequester inorganic constituents, and concentration of COPCs between 0.5 and 5 times the screening value. Similar zones can be described for the portion of Little Timber Creek Swamp between U.S. Route 130 and Cedar Swamp Road. The three zones are depicted on a recent aerial photograph of the site (Figure 15). The boundaries between the three zones have been estimated based upon the existing data. The Phase 2 RI/FS will provide information to refine these boundaries and the criteria used to distinguish each zone. The Phase 2 RI and the ecological risk assessment will target the assessment of COPC fate and transport, and the distribution of COPCs relative to receptors. In the Phase 2 FS, the ecological risk managers will utilize the RI information to balance risk reductions with the injuries that can result from remedial actions.

Of the metals detected, lead was found in many of the sediment samples at concentrations exceeding the PRGs consistently throughout the area (Figure 16). Other inorganics, including antimony, arsenic, barium, cadmium, chromium, copper, nickel, silver, zinc and cyanide were detected in one or more sediment samples in excess of the PRGs. Sediment sampling at reference areas will be conducted to assess the potential that some of the inorganics are representative of background conditions.

TPH was detected at concentrations exceeding 100,000 mg/kg in five samples (T1-S1, T1-S2, T1-S3, T2-S4, and T3-S5) indicating that residual petroleum-related compounds exist in the wetlands (Figure 16). The highest concentrations of TPH generally corresponded with the samples for which SVOCs and PCBs could not be analyzed due to extraction problems. Also, the locations of the highest concentrations of lead correlated with the locations of the highest concentrations of TPH (0.89 correlation coefficient).

VOCs were detected in three sediment samples all from transect T1 (T1-S1, T1-S2, and T1-S3) at concentrations exceeding the PRGs. The VOCs detected were primarily petroleum related compounds (e.g., toluene). Chlorinated solvents, specifically PCE and 1,2-dichloroethene, were detected at concentrations exceeding the PRGs from T1-S1. No other samples from any of the transects detected concentrations of VOCs exceeding the PRGs. Several tentatively identified compounds were reported in a number of samples. Acetone was detected in several samples, including the blanks, indicating that it was either a field or laboratory introduced contaminant.

Although SVOCs were analyzed, results were not reported for nine samples due to problems during extraction. Numerous unidentified hydrocarbons were reported in the library search. Of the targeted SVOCs identified, most were PAHs. The following PAHs were detected in the samples noted above the PRGs: phenanthrene (T1-S4 and T3-S4), fluoranthene (T3-S4), and pyrene (T3-S3 and T3-S4). The concentrations of the individual PAHs exceeded the PRGs by an average of two times. It is not possible to accurately evaluate gradients of SVOC COPCs due to the incomplete data sets, although CH_2M Hill (1992) concluded that the highest concentrations of PAHs occurred closer to the center of the wetlands. The entire area will be resampled as part of this Work Plan.

PCB analysis was not completed for the same nine samples as those not analyzed for SVOCs due to extraction problems. PCBs were detected in nine samples at concentrations exceeding the PRGs. Aroclor 1260 was the dominant isomer detected; however, Aroclor 1254 was detected at elevated concentrations with respect to the PRG in sample T3-S2.

2.5.6.2 Gaventa Pond

The highest concentrations of COPCs detected in Gaventa Pond are found in GVP-01, which is closest to the former lagoon and former seep area (Figure 2). GVP-01 was collected was within a boomed area of the pond which was set out to contain floating product or a sheen. It is possible that the COPCs were introduced as sampling equipment was lowered through the sheen. The extent of COPCs in the sediments in the northeast corner of Gaventa Pond has not been defined and will be investigated in the Phase 2 RI as discussed in Section 6.3.1.

Three sediment samples were collected from Gaventa Pond (Figure 14). No VOCs or SVOCs were detected in the Gaventa Pond sediment samples which exceeded the PRGs. Aroclor 1260, a PCB mixture, was detected in sample GVP-01 which exceeded the PRG. Neither of the other two samples had PCBs detected. Several metals were detected at concentrations that slightly exceeded the PRGs that, with the exception of lead, is most likely related to background concentrations. The highest concentrations of metals were detected in sample GVP-02 which was collected outside of the boom to the west of sample GVP-01. A TPH concentration of 22,629 mg/kg, exceeding the PRG of 10,000 mg/kg, was detected in GVP-01. A TPH concentration significantly lower than the PRG was detected in sample GVP-02.

2.5.6.3 Swindell Pond

Two sediment samples were collected from Swindell Pond (Figure 14). No VOCs, SVOCs or PCBs were detected at concentrations exceeding the PRGs. Again, acetone was detected in the VOC analysis and was also found in the blanks indicating that it is a laboratory or field introduced contaminant. Several metals (arsenic, chromium, copper, lead, and zinc) were detected at concentrations slightly exceeding the lowest effects screening levels (Table 2). The extent of COPCs in sediments in the vicinity of SDP-02 will be investigated in the Phase 2 RI as discussed in Section 6.3.1. This limited investigation is proposed for the sediments in Swindell Pond during the Phase 2 RI for the following reasons:

- the concentrations of metals detected slightly exceed the effects screening criteria;

- the concentrations of metals detected were well below the severe effect level (SEL) of the aquatic sediment quality guidelines proposed by Persaud (1993) at which their concentration in the sediment would be likely to affect the health of sediment-dwelling organisms;

- although Swindell Pond is a steep-sided pond, as it was created by sand mining operations and consequently is predicted to have relatively small and activity of ecological receptors, the biological communities of Swindell Pond have not been characterized;

- secondly, the pond can be directly connected to the Little Timber Creek wetlands during high water periods; and

- hydrologic data as well as a surface water and sediment samples collected immediately adjacent to Swindell Pond in the Little Timber Creek Swamp will be evaluated with surface water and sediment samples from the pond to assess the potential significance of the limited connection between these two areas.

3.0 PRELIMINARY IDENTIFICATION OF ARARS AND PRGS

3.1 Preliminary Identification of ARARs

A preliminary identification of potential ARARs and To-Be-Considered information (TBCs) has been prepared in accordance with Section 121 (d) (2) (A) of the Comprehensive Environmental Response and Liability Act (CERCLA) to assist in the scoping of remedial technologies, to support the planning of Phase 2 RI/FS activities and to begin the process of soliciting input from support agencies. An ARAR is defined as:

1. Any standard, requirement, criterion, or limitation under federal environmental law, or

2. Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility citing law that is more stringent than the associated federal standard, requirement, criterion, or limitation.

TBCs include standards, policies, and guidance that have not been promulgated as law. ARARs and TBCs fall into the following three broad categories, based on the situation which they apply at the site:

1. Chemical-Specific (such as MCLs).

2. Location-Specific (such as wetlands and historic districts).

3. Action-Specific (such as National Pollutant Discharge Elimination System [NPDES] requirements, hazardous waste manifesting, or Occupational Safety and Health Administration [OSHA] requirements).

Preliminary lists of chemical-specific, location-specific, and action specific ARARs and TBCs are provided in Tables 3 through 5, respectively.

Other TBC information for the Phase 2 RI/FS includes:

Land Use in the CERCLA Remedy Selection Process. OSWER Directive 9355.7-04. (USEPA, 1995b)

Notice of Availability of "Land Use in the CERCLA Remedy Selection Process." 60 FR 29595. (USEPA 1995b)

Final Guidelines for Exposure Assessment. 57 FR 22888. May 29, 1992. (USEPA 1992a)

Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors" OSWER Directive 9285.6-03. (USEPA, 1991a)

Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30. (USEPA, 1991b)

These lists will be updated and revised during the Phase 2 RI/FS and each ARAR and TBC will be evaluated relative to its relevance and appropriateness.

3.2 Preliminary Remediation Goals

Initial Preliminary Remediation Goals (PRGs) have been developed for the BROS site to:

- serve as basis for the evaluation of existing site data in order to identify data needs;
- support the preliminary screening of remedial technologies and alternatives; and
- facilitate the preliminary development of site-specific Data Quality Objectives (DQOs), in consideration of the matrix complexities and limitations particular to the site (USDC 1997a).

In general, the initial PRGs are based upon the ARARs and TBCs described in Section 3.1. As such, they are predominantly published guidelines and standards. As the initial PRGs will be used to support the development of DQOs for the QAPP, alternative references were consulted to

supplement the initial PRGs. Numeric DQOs for the analytical methods to be used for the analysis of samples collected as part of the Phase 2 RI/FS have been established (Tables 6A through 6D). In order to accurately evaluate concentrations of COPCs, the numeric DQOs for the BROS property, the area between I-295 and Route 130; and Little Timber Creek Swamp west of Route 130 have been set at 50% of the PRG. The selection of 50% of the PRG is intended to allow for anticipated difficulties in meeting the method detection limit due to matrix interference, while providing a low enough numeric DQO to protect against changes in regulatory standards and potential measurement errors. This approach is consistent with guidance provided in RAGS Part A (USEPA, 1989a), RAGS Part D (USEPA, 1998f) and the *Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997b). For the remaining areas, the numeric DQOs will be the method detection limit.

As outlined in Task VIB, a component of the risk assessment will entail the development of PRGs for COPCs where no ARAR or TBC-specific value has been established. PRGs will be frequently reevaluated and modified throughout the Phase 2 RI/FS, as new data is developed. Site-specific PRGs will be developed within the context of risk assessment principles and may include, for example, the application of published toxicological data and site-specific exposure assumptions to develop alternative concentration limits.

The initial PRGs for soils are the NJDEP Soil Cleanup Criteria (SCC) as published on July 11, 1996. Initial PRGs for the BROS property will be the more stringent of the Restricted Use or Impact to Ground Water SCC. The initial PRGs for the off-property areas will be the more stringent of the Unrestricted Use or Impact to Ground Water SCC. If a compound is detected that does not have a an established NJDEP SCC, the generic Soil Screening Levels (SSLs) provided in Table A-1 of the USEPA publication *Soil Screening Guidance: Users Guide* (USEPA, 1996b) will be used as the initial PRG. A summary of initial PRGs for COPCs in soil based on historical site data is provided (Table 6A).

The initial PRGs for ground water are the more stringent of the New Jersey Ground Water Quality Standards for Class II-A Aquifers (N.J.A.C. 7:9-6.9) or the Maximum Contaminant

Levels (MCLs) at 40 CFR 141. Additionally, the surface water quality standards described below may be applicable to the Upper PRM aquifer where it discharges to surface water. A summary of initial PRGs for COPCs in ground water based on historical site data is provided (Table 6B).

The initial PRGs for surface water will be the lower of the New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B-1.14) or the Ambient Water Quality Standards at 40 CFR 131.36. The Delaware River and Basin Commission (DRBC) Stream Quality Objectives (SQOs) published in the *Delaware River Basin Water Code* (DRBC, 1996) may be applicable to surface water discharges generated during remedial activities. A summary of initial PRGs for COPCs in surface water based on historical site data is provided (Table 6C).

The initial PRGs for sediments are the more stringent of the lowest effects level (LEL) from *the Guidelines for the Protection and Management of Aquatic Sediments Quality in Ontario*, as published by the Ontario Ministry of Environment and Energy (Persaud *et. al.*,1993) or the Apparent Effects Thresholds (AETs) from the *Creation and Analysis of Freshwater Sediment Quality Values in Washington State.* The Ontario and Washington State guidelines were applied as they are based upon potential effects in freshwater systems - although much of the data used to develop the Ontario guidelines comes from lake ecosystems (i.e. the Great Lakes region) and may not be an appropriate match for the stream and marsh ecosystems in the vicinity of the BROS site. If an LEL or AET does not exist for a compound, then the effects range low (ER-L) from *Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments* (Long et. al 1995) was used. The use of freshwater or estuarine guidelines in establishing PRGs for wetlands sediments will be reevaluated based upon the further assessment of site-related hydrology as part of the Phase 2 RI.

If an LEL, ER-L or AET does not exist for a compound, then the Sediment Quality Benchmark (SQB) from *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment Associated Biota* published by the Oak Ridge National Laboratory (Suter *et. al.*, 1994) will be used. A summary of initial PRGs for COPCs in sediment based on historical site data is provided (Table 6D).

4.0 PRELIMINARY SCREENING OF REMEDIAL TECHNOLOGIES, IDENTIFICATION OF POTENTIAL ALTERNATIVES AND ASSOCIATED DATA NEEDS

As discussed in Section 2.0, the media of concern at the site are ground water, LNAPL, DNAPL, surface water, sediments, incinerator ash, soil, and lagoon residuals. Preliminary identification and screening of remedial technologies for the media of concern has been performed to provide a general listing of candidate technologies and to identify potentially suitable remedial alternatives and associated data needs. As the Phase 2 RI/FS data becomes available and the iterative steps of the baseline risk assessment are completed, the identification and screening of remedial technologies will be updated. Where appropriate, various AOCs or hot spots will be evaluated separately and in combination with the site conditions. This process develops an appropriate range of waste management options and ensures that data needed to perform a detailed evaluation of remedial actions during the FS is collected as soon as practicable and to identify useful treatability studies in a timely manner. The preliminary identification and screening of remedial technologies is performed in accordance with the NCP, Tasks I and IV of Appendix E of the BROS Consent Decree and with the guidelines of the USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a). The process is performed in the following steps:

- develop preliminary remedial action objectives;
- identify candidate remedial technologies and process options;
- screen remedial technologies and process options;
- identify potential remedial alternatives; and,
- identify data needs.

Each of the above-described steps is discussed in Sections 4.1 through 4.5. The data needs portion of this section (Section 4.5) includes an identification of potential candidate technologies for treatability study testing and the likely treatability study objectives (Consent Decree Appendix E, Task IV). Current site-specific data will be used to select candidate treatability studies, in accordance with the Phase 2 RI/FS schedule approved by the USEPA.

4.1 Identification of Preliminary Remedial Action Objectives (PRAOs)

Preliminary remedial action objectives (PRAOs) consist of media-specific goals for protecting human health and the environment within the context of likely exposure pathways. The PRAOs for the BROS site have been developed from the PRGs outlined in Section 3.2 and the conceptual site model. The PRAOs used for the preliminary screening of remedial technologies and alternatives for soil, ground water, surface water, and sediments are identified below.

Soil, Incinerator Ash, and Lagoon Residuals

The PRAOs for soil, incinerator ash, and lagoon residuals are to increase sequestration, reduce bioavailability, reduce mobility, reduce toxicity, prevent ingestion and direct contact of media exceeding prescribed health risks, and prevent the movement of contaminants to other media. The PRGs for these media include the NJDEP SCC and the USEPA SSL.

Ground Water and NAPL

The screening PRAOs for ground water and NAPL are to increase sequestration; reduce bioavailability; reduce mobility (for both the free product and aqueous forms); reduce toxicity; prevent inhalation, direct contact and ingestion of ground water exceeding MCLs, the NJ GWQC or applicable risk-based standards, and restore ground water quality to the applicable standards. Previous remedial actions such as providing municipal water supply to residents near the BROS property have been performed and have minimized the potential for ingestion. Eliminating, reducing, and/or controlling potential exposure to contaminated ground water will continue to be of primary importance throughout the RI/FS and remedial action process for the site. Where ground water contains, or will contain, contaminants in excess of the NJ GWQC, an application for a Classification Exception Area (CEA) designation is being prepared to minimize the potential for exposure that may result from the drilling of new supply wells during the Phase 2 RI/FS and remedial period. The CEA process has been initiated based upon USEPA concurrence. Initially, the CEA will be established for portions of the Upper PRM and the Upper Middle PRM over the area underlying the BROS property and the surrounding area based on the available data, pursuant to applicable NJDEP requirements. The CEA is entered into an NJDEP database that is used by the Bureau of Water Allocation when well permit applications are received. When

ground water users are identified at the BROS site during the RI/FS, extension of the municipal water to supply the residence will be proposed as a remedial action to eliminate potential exposure.

The second part of the objective, to restore ground water concentrations to the remedial goals, to the extent practicable, is retained as an overall objective in accordance with the NCP. While ground water restoration to drinking water quality standards remains an overall goal, the USEPA and the environmental industry recognize that technical impracticalities to restoration exist which limit the feasibility of this objective in some situations (USEPA 1993a). More feasible objectives in some cases are include: (1) focusing on remedial technologies that treat the principal threats which maximizing risk reduction (Linz and Nakles, 1997), and (2) developing an alternative concentration limit (ACL) or controlling the potential for ingestion of water exceeding health-based concentrations. ACLs can be considered, within the context of the National Contingency Plan (40 CFR 300.430), based upon the practicability of restoration. The term "practicability" within the context of the National Contingency Plan, is related to the appropriateness of restoration based upon the Superfund remedial selection criteria (USEPA 1993d).

The NCP also specifies the conditions when ground water ACLs may be established for ground water discharging to surface water through a citation in CERCLA [Section 121(d)(2)(B)(ii)]. These conditions include an understanding of the known or projected points of discharge, a demonstration of no significant increases in contaminant concentrations in the surface water body, and prevention of human exposure through institutional controls. The Phase 2 RI/FS scope of work has been developed to provide data to support the analysis of ground water/surface water interactions relative to COPC fate and transport as a means of supporting the evaluation of ACLs.

Surface Water

The screening PRAOs for surface water are to increase sequestration, reduce bioavailability, reduce mobility, reduce toxicity, prevent ingestion of and direct contact with surface water exceeding prescribed human health and ecological risks, and prevent the migration of contaminants via surface water, including migration into ground water and uptake through the

food chain. The PRGs for surface water include New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B-1.14), the Ambient Water Quality Standards at 40 CFR 131.36 and DRBC criteria.

Sediments

The screening PRAOs for sediments are to increase sequestration, reduce bioavailability, reduce mobility, reduce toxicity, prevent direct contact with sediment exceeding prescribed human health and ecological risks, prevent the migration of contaminants from sediments through the food chain and into ground water and surface water, and to minimize disturbance to the sensitive wetland ecosystem. As discussed in Section 3.2, the PRGs for sediments are the Ontario LELs although other sediment guidelines have been employed where LELs are not available.

4.2 Identification of Candidate Remedial Technologies and Process Options

The preliminary candidate technologies, and process options including innovative technologies, have been identified (Table 7). In accordance with USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a) the candidate remedial technologies are general categories of technologies such as chemical treatment, thermal destruction or capping. Several potential process options may be included within the technology type. For example, *in-situ* treatment of ground water includes the process options of aerobic bioremediation, anaerobic bioremediation, biosparging, natural attenuation, reaction walls, and *in-situ* oxidation, including chemical sources of oxygen.

The candidate technology and process options have been assembled in accordance with available guidance documents. Generally, remedial technologies and process options were developed based on available guidance documents such as *Remedial Action at Waste Disposal Sites* (USEPA, 1985d) and *Treatment Technologies* (USEPA, 1990b) and media-specific guidance documents have been consulted where applicable. For example, candidate containment technologies and process options have been developed from guidance documents such as *Covers for Uncontrolled Hazards Waste Sites* (USEPA, 1985c), *Design and Construction of Cover for Solid Waste Landfills* (USEPA, 1989b), and *Slurry Trench Construction for Pollution Migration Control*

(USEPA, 1984). Candidate remedial technologies and process options for media such as soils, incinerator ash, and lagoon residuals have been developed based on *Guidance on Presumptive Remedies Site Characterization and Technologies Selection for CERCLA Sites with Volatile Organic Compounds in Soils* (USEPA, 1993e), *Technology Screening Guide for Treatment of CERCLA Soils and Sludges* (USEPA, 1988b), *A Compendium of Technologies Used in the Treatment of Hazardous Waste* (USEPA, 1987), *Systems to Accelerate In Situ Stabilization of Waste Deposits* (USEPA, 1986a), and *Handbook for Stabilization/Solidification of Hazardous Wastes* (USEPA, 1986b). These guidance documents will continue to be utilized throughout the RI/FS process.

Within the FS process, the evaluation of candidate technologies is principally a function of implementability and effectiveness based upon the RI data and site characteristics. This approach was applied to the Work Plan scoping effort as well, although the screening employed a greater latitude based upon the current data needs and the objective of developing a comprehensive, yet decision-relevant, data collection program. The screening also considered the variability between differing areas of the site (e.g. the Little Timber Creek Swamp as compared to the Gaventa Pond, incinerator wastes as opposed to soils in the former Process Area) and technologies and process options were retained even if they are likely to be limited to specific areas of concern. The results of the technology screening were carried through to the preliminary development and screening of remedial alternatives (Section 4.2).

4.3 Screening of Remedial Technologies and Process Options

Screening of remedial technologies and process options is performed to streamline the RI/FS process and focus the data-gathering activities to the collection of decision-relevant data (i.e. that necessary to support the detailed analysis of remedial alternatives in the FS), while ensuring that the most promising options are being considered. The remedial technologies and process options are preliminary screened in accordance with the following screening criteria which are stipulated in the NCP and noted in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA:* (USEPA, 1988a), Chapter 4 of *Risk Assessment Guidance for Superfund (RAGS) Part D. Standardized Planning, Reporting and Review of Superfund Risk Assessments* (USEPA, 1998f), and other relevant guidance discussed in Section 4.2:

- effectiveness (long-term and short-term);
- implementability; and,
- cost.

The effectiveness evaluation focuses on the degree to which a technology and process option reduces toxicity, mobility, or volume through treatment, minimizes residual risks, and affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection. The effectiveness of technologies and process options and technologies is ranked to be high, moderate, or unlikely. Technology and process options providing significantly less effectiveness, as characterized by protectiveness of human health or the environment, are eliminated.

The implementability evaluation for technologies and process option focuses on whether the options are technically and administratively feasible. The implementability of the technologies and process options is ranked to be high, moderate, or unlikely.

The cost of the technologies and process options is evaluated to provide a measure of comparison of overall capital and operation and maintenance costs among technologies and process options based on current information and engineering judgment. Costs that are grossly excessive compared to the overall effectiveness may be eliminated. Technologies and process options providing effectiveness and implementability similar to that of another alternative by employing a similar method of treatment or engineering control, but at a greater cost, may be eliminated. The relative cost of technologies and process options is ranked to be very high, high, moderate, or low.

The preliminary screening of the technologies and process options has been summarized (Table 7). Alternate water supply and use restrictions have been implemented and considerable source removal has been performed so the preliminary screening was conducted within this context. Generally, many of the identified technologies and process options have been retained due to the relative complexity of the site, the desire to ensure that RI data collection is comprehensive and

the possibility of employing an array of technologies and process options in the ultimate site remedial action. Retained technologies and process options will be used to identify RI data needs, as discussed in Section 4.5. Technologies and process options will be routinely reevaluated as the RI activities proceed, based upon a consideration of new site-specific data and current information on emerging technologies, in order to refine subsequent RI data collection activities. Technologies and process options will be more fully evaluated as part of the FS, as outlined in Section 6.9.

4.4 Remedial Action Alternatives

The range of alternatives includes some alternatives where treatment reduces the toxicity, mobility, or volume of the hazardous substances. Other alternatives include treating the principal threats posed by the site but vary in the degree of treatment employed and the quantities and characteristics of the treatment residuals and untreated waste that must be managed. The evaluation of ground water response actions will include a limited number of remedial alternatives that attain site-specific remediation levels within different restoration time periods utilizing one or more different technologies. Remedial action alternatives can be grouped into the four categories:

- no action
- institutional controls;
- source control; and
- residuals management (ground water, soils, and sediment beyond the primary source area).

During the FS, each alternative will be screened in a manner consistent with the NCP with the final alternatives compared in relation to the nine criteria listed in the NCP. In addition, the final remedial alternatives under consideration will be evaluated based on relative costs and cleanup benefits to ensure cost-effectiveness, as emphasized in the Superfund Administrative Reforms (October, 1995). An evaluation of the functional equivalency with the National Environmental Policy Act (NEPA) will also be included (USEPA, 1988c).

The "no action" alternative is used to evaluate the need for remedial action and provide a basis for comparison with other remedial technologies and alternatives, as required by the NCP. Institutional controls remedies may include institutional measures, for example, deed restrictions, ground water use restrictions and monitoring. While these alternatives are likely appropriate for certain media or portions of the site, it is likely that these alternatives will be included as elements of the overall remedial approach for a particular media, area of concern or hot spot in conjunction with other alternatives or technologies.

Source control alternatives include containment technologies, stabilization measures, removal activities and similar processes to mitigate the transport of COPCs to receptors at concentrations exceeding risk-based levels. In addition to concentrated waste materials (e.g. LNAPL, lagoon residuals), source control alternatives are potentially applicable to those areas of ground water contamination and sediments that are found to be contributing COPCs to potential exposure pathways and resulting in unacceptable risk to receptors, such as the *de manifestis* zone in the wetlands. Source control measures considered in the preliminary screening include a range of actions including:

- treatment alternatives that minimize the need for long-term management (e.g., excavation and removal);

- alternatives that employ active treatment (e.g. pump and treat, LNAPL extraction) but vary in the degree of treatment and the quantities and characteristics of treatment residuals warranting further management; and

- alternatives that rely upon containment with little or no treatment (e.g. capping, barriers).

Where appropriate based upon the RI and risk assessment data, specific remedial alternatives will be established for individual media types, areas of concern or hot spots. The range of source control measures for soils includes alternatives capable of addressing incinerator ash; lagoon residuals; soils in the former Process Area; surface soils in contact with LNAPL; subsurface soils in contact with NAPL; soils in the wetlands; and off-property soils, such as those in the drainage

swale and the peach orchard. Due to the variabilities in physical and chemical parameters between these different materials, and their differences in potential exposure pathways and receptors, a variety of source control alternatives have been retained through the preliminary screening.

Source control measures for sediments include many of the alternatives applicable to soils, but the preliminary evaluation is influenced by differences in effectiveness associated with the distinct hydrologic and receptor conditions associated with sediments. Source control measures applicable to surface water include traditional methods such as diversion and retention, as well as innovative approaches such as constructed wetlands treatment.

Source control measures for ground water are more directly applicable to areas of LNAPL and ground water areas of concerns or "hot spots" that continue to serve as a source of COPCs to other media or portions of the site; resulting in either an exceedance of the site-specific PRAOs or extended restoration timeframes. Source control measures for ground water include innovative technologies such as air sparging, reaction walls and horizontal well treatment systems.

Residuals management alternatives are employed to address contaminated media beyond the primary source area. These alternatives typically address relatively low concentrations of COPCs over a larger area than the source control alternatives. Residuals management alternatives include biosparging, natural remediation, stabilization, ground water pump and treat, vegetative covers, capping, and armoring.

A list of potential remedial alternatives for each of the media in each of the categories described above is included (Table 8). The *EPA Guidance on Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils* (USEPA, 1993e) presents a detailed discussion of potential remedial alternatives for soil impacted with VOCs. Specifically, the guidance document identifies soil vapor extraction (both *in-situ* and *ex-situ*), thermal desorption, and incineration as presumptive remedies. These technologies have been included as candidate technologies; however, their applicability at the

BROS site may be limited due to site conditions. For instance, the lagoon residuals are located beneath incinerator ash, a location which makes these technologies impractical. These technologies have been retained and will be further evaluated in detail in the FS.

The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites* (USEPA, 1996c) presents a detailed discussion of potential remedial alternatives for ground water. The Presumptive Remedy guidance was consulted in the identification and screening of potential remedial alternatives. The objective of the presumptive remedies initiative is to "...use the Superfund program's past experience to streamline site investigations and accelerate the selection of cleanup actions." Key elements of the Presumptive Remedy guidance that apply to the screening of remedial alternatives for the BROS site are:

- the preference for phased remedial actions;
- consideration of restoration timeframes as a component of effectiveness and implementability; and
- recognition of alternative response strategies including natural attenuation, technical impracticability, and ACLs.

The Presumptive Remedy guidance recommends that remedial actions be phased in order to utilize a growing body of site-related data to "characterize the site and assess restoration potential"; set objectives for each response phase; provide flexibility to adjust remedies; respond to site conditions; increase remedy performance and decrease remedy timeframe; and to incorporate remedy refinements. The Presumptive Remedy guidance identifies the following general phases:

- exposure prevention, including providing an alternate water supply and use restrictions;
- source removal, including excavation of impacted soils;
- migration prevention; and
- assess restoration potential.

Alternate water supply and use restrictions have been implemented at the BROS site and considerable source removal has been performed so the development of potential remedial alternatives was conducted within this context. The potential migration pathways and ground water restoration potential are being assessed by through the RI data collection and ground water modeling activities outlined in Section 6.0. The preliminary remedial alternatives development reflects the potential for a phased remedial approach and alternatives have been retained for residuals management.

As described previously, the NCP and the Presumptive Remedy guidance specify a comparison of ground water response actions with differing timeframes. Where restoration is feasible using both aggressive and passive methods, the most appropriate remedial option should be determined based upon the nine remedy selection criteria in the NCP (40 CFR 300.430). As such, potential remedial alternatives will not be eliminated during the preliminary remedial alternatives analysis solely due to restoration timeframe.

The Presumptive Remedy guidance and the NCP recommend the use of natural attenuation where it is "expected to reduce the concentration of contaminants in the ground water to the remediation goals (ARAR or risk-based cleanup levels) in a reasonable timeframe". Natural attenuation will be evaluated as a remedial alternative to varying degrees across the site, including as a component of remedial alternatives employing other measures designed to remediate hot spots. Additional information about pump and treat technologies, technical impracticability and natural attenuation has been provided in the appendices to this Work Plan. This information, which includes several additional references, is provided as background for the public and other readers who need a technical summary on these issues and do not have ready access to guidance documents. Additional discussion of technical impracticability is presented in Appendix A. The current status of pump and treat technologies as a method of achieving MCLs is more fully discussed in Appendix B. Natural attenuation considerations are more fully discussed in Appendix C. In general, all of the various technologies and their limitations will be evaluated in greater detail when more alternative screening level relevant data are obtained in the Phase 2 RI. The site-specific information will be evaluated in matrix form consistent with EPA guidance, such as Table 1

in *Pump-And-Treat Ground-Water Remediation, A Guide for Decision Makers and Practitioners*, 1996.

4.5 Identification of Data Needs

Although there has been considerable evaluation of the former lagoon over the previous two decades, relatively little data has been obtained on soils and LNAPL beyond that collected through the post-excavation samples and the more recent Phase 3 investigation. Consequently, the identification and screening of alternatives is limited by the high degree of uncertainty associated with such design relevant factors as: the extent of contamination; site-specific geotechnical and geochemical properties that relate to the selection and sizing of equipment; and hydrogeologic properties of the aquifers at the site. In order to perform a detailed evaluation of remedial technologies and alternatives in the FS, certain data will be acquired during the RI. While a primary objective of the RI is to delineate and characterize the contamination, media, and physical properties of the site in relation to potential receptors; certain data must be collected to provide for detailed evaluation of remedial technologies and alternatives. These data include geotechnical parameters, concentration trends, conventional water parameters, thermal parameters, and ecological assessments. Treatability studies and/or pilot-study testing may also be performed, as discussed later in this section.

Geotechnical parameters include items such as permeability, porosity and grain size. These parameters are necessary for environmental fate and transport analysis, and in the conceptual design and evaluation of remedial alternatives.

Concentration distributions, especially for chlorinated solvents in soils , are not known and such gradient information provides a measure of the ongoing fate and transport of contamination at the site, which is essential in forecasting site conditions over time. This is useful for evaluating any long-term remedial actions and determining whether source removal actions have been effective in reducing the mobility of contamination residuals.

Conventional water parameters are useful in assessing treatment requirements (both *ex-situ* and *in-situ*) of ground water or surface water. Conventional water parameters include alkalinity, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), total organic carbon (TOC), hardness, iron, manganese, and specific gravity (of free product).

Geochemical parameters are necessary for assessing *in-situ* alternatives and technologies. Geochemical parameters include soil carbon content, dissolved oxygen in water, pH, Eh, temperature, conductivity, nitrate, nitrite, oxidation/reduction potential, carbon dioxide, methane and nitrogen.

Thermal parameters are useful in assessing *ex-situ* treatment alternatives and technologies such as thermal desorption or incineration. Thermal parameters include ignitability, reactivity, total organic halides (TOX), moisture content, and toxicity characteristic leaching procedure (TCLP) parameters.

Ecological assessments are necessary to gain a thorough understanding of media interactions and potential effects of remedial actions on sensitive ecological receptors.

Treatability Studies

The scoping of pilot testing and treatability studies will be completed during the early stages of the RI. In accordance with the approved schedule, the draft Treatability Study Work Plan will be provided to the USEPA five months after the approval of the Phase 2 RI/FS Work Plan. The RI scope of work has been designed to generate sufficient data to scope the treatability studies within the timeframe required for Treatability Study Work Plan preparation.

Treatability studies may be required to assess the likely efficacy of selected potential remedial technologies. Moreover, treatability studies can reduce cost and performance uncertainties and facilitate the FS and remedial selection processes. The selection, citing and design of these studies will be completed based upon the preliminary results of contaminant delineation and the

geochemical and geotechnical properties of the site. For example, prior to designing a biosparging pilot test the following information should be evaluated:

- the current nutrient and contaminant concentrations in the study area;
- evidence of biodegradation of contaminants (i.e. daughter products and physical/chemical data trends);
- the likely type(s) of biodegradation that will occur based upon contaminant properties and geochemical conditions in the study area;
- the stratigraphy of the sparging and treatment zones;
- the permeability of the sparging and treatment zones; and
- ground water flow rate and direction.

Potential remedial technologies that may require treatability studies are listed in the table on the following page, along with a general outline of the study objectives.

Remedial Technology	Study Objectives
Air Sparging	Assess injection rates, depths and spacing; vapor recovery and treatment; iron fouling and long term removal rates.
Ex-Situ Ground Water Treatment	Pending results of the ground water characterization during the pumping tests, establish efficiencies and costs of potential treatment methodologies in context of likely discharge limitations to support technology selection and costing for FS.
Biosparging	Evaluate injection rates, depths and spacing; need for vapor recovery; and iron fouling. Assess biological growth and contaminant removal.
Enhanced *In-Situ* Bioremediation	Assess alternative nutrient and electron acceptor supplements and feed rates. Assess injection methods. Evaluate performance of technology.
Natural Attenuation	Assess processes that effect adsorption, dispersion, dilution, chemical degradation and biological degradation of COPCs.

Remedial Technology	Study Objectives
Soil Vapor Extraction	Evaluate extraction rates, locations, depths and spacing; preferential flow paths and long term effectiveness. Assess vapor treatment requirements.
Reaction Wall	Evaluate media types and removal efficiencies. Assess media replacement/maintenance rates.
Constructed Wetlands	Evaluate media types and removal efficiencies. Assess maintenance requirements.
Solidification	Evaluate mixture ratios and effectiveness.

The development of the Treatability Study Work Plan will be based upon the results of RI activities completed at the time it is prepared, including the results of ground water sampling and investigations of secondary source areas. In some instances, treatability studies identified in the Treatability Study Work Plan may be completed after much of the RI data collection is complete. For example, studies to assess the effectiveness of different sparge media (e.g. methane, air) in biosparging should be focused to specific contaminant types and hydrogeologic settings. Scoping treatability studies that provide information about the applicabilities and limitations of the biosparging technology, and avoiding unnecessary studies, will require site-specific ground water and saturated soils data that may not be available until several months into the RI.

The data collected as part of this Phase 2 RI/FS, in conjunction with reference information about the application of remedial technologies, will be used to focus the treatability study objectives and reduce the number and extent of treatability studies conducted. The Treatability Study Work Plan will provide the timing, objectives and rationale for each planned study. The criteria that will be used to select remedial technologies for treatability study testing are based upon the considerations outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA:* (USEPA, 1988a) and the BROS Consent Decree (USDCa) and will include:

- the adequacy of existing and anticipated data for the screening and evaluation of alternatives;

- the probability of effectiveness of the technology for the BROS site, based upon published and vendor data -- including demonstrated success with similar contaminants and environmental settings;

- the likely cost of the remedial technology, relative to other technologies that are likely to be effective for the site;

- the probability that the treatability study will yield meaningful cost or performance data; and

- whether the treatability study is needed to establish the effectiveness and probable cost of the technology, in support of the FS; or whether it can be completed, at least in part, during the remedial design.

5.0 WORK PLAN RATIONALE

The Work Plan details the Phase 2 RI/FS activities necessary to support the selection of remedial activities for soils, sediments, surface water, wetlands and ground water at the BROS site. The Work Plan has been developed based upon existing site data and reflects relevant federal and state laws, regulations and guidance and an assessment of the recent scientific literature relative to hazardous waste site investigation and remediation. The Work Plan addresses the Phase 2 RI/FS data needs identified through the scoping process and as presented to the USEPA, NOAA and NJDEP during the scoping process meetings. The Phase 2 RI/FS objectives, followed by the objective-specific data needs are briefly summarized in Section 5.1. A summary of the Phase 2 RI/FS DQOs is provided in Section 5.2. These objectives and data needs form the basis for the development of the Phase 2 RI/FS scope of work described in Section 6.0.

5.1 Phase 2 RI/FS Objectives and Data Needs

The primary objectives of the Phase 2 RI/FS were stated in Section 1.0. The specific objectives are a function of the data needs. Phase 2 RI/FS data needs have been developed based upon the information developed for the BROS site to date, a preliminary evaluation of the potential remedial action objectives and ARARs, and potential remedial alternatives and technologies for the site. The Phase 2 RI/FS data and technical evaluation needs summarized below were identified and refined during the Work Plan scoping process. These data will supplement the existing data, fill data gaps, and support the assessment of remedial alternatives. How the data needs and Phase RI/FS objectives have been integrated into the Phase 2 RI/FS scope of work is discussed in more detail in the remainder of this section.

Objective 1 - Establish a Water Budget for the Site

The assessment of the water budget for the BROS site focuses upon the evaluation of ground water - surface water interactions and the investigation of aquifer and stream/wetland properties. The water budget evaluation will be used to refine and validate the conceptual site model, ultimately providing the platform for modeling the fate and transport of COPCs in support of the HHRA, the ERA and the FS. For the Phase 2 RI/FS the water budget study area will be focused

between Routes 130 and I-295, with specific emphasis on the ponds and wetlands; although a broader regional framework will be considered through limited investigations in Cedar Swamp, the Little Timber Creek wetlands south and east of Route 295, and reference data available through the United States Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), the New Jersey Department of Transportation (NJDOT), the Delaware River Basin Commission (DRBC) and information developed at the CLTL site.

Data and Technical Evaluation Needs:

- Establish the direction and magnitude of water movement through various environmental compartments at the site, especially the discharge/recharge relationship between ground water and surface water.

- Understand the fluctuations in flow and discharge/recharge relationships caused by seasonal changes and precipitation events.

- Determine the relative potential for contaminant movement through aqueous pathways; soil leaching, incinerator ash/lime leaching, ground water movement, and surface water transport.

- Evaluate the effects of various potential remedial alternatives (i.e., capping, pumping and treatment, engineering containment) on the movement of water and associated contaminants as well as on the hydrology of the adjacent wetlands.

The water budget analysis, linked with other sampling and evaluation activities, will satisfy the data needs identified above. Based on the water budget evaluation results, the conceptual site model will be refined and provide the template for the fate and transport assessment which will be used in human health risk assessment, ecological risk assessment, and the Phase 2 FS.

Objective 2 - Establish the Spatial Distribution, Volume and Mass of Contaminants Associated with Residual Source Areas

LNAPL areas and potential contaminant sources have been identified (Section 2.5.1). These sources can be a substantial ongoing contributor of COPCs to ground water and wetlands. The

determination of the distribution, volume and mass of LNAPL is a specific objective of the RI. Further, the characteristics, distribution, mobility and recoverability of contaminant sources will be a key factor for the risk assessment and the FS.

Data and Technical Evaluation Needs:

- Determine the vertical and horizontal distribution of free product; defined as the LNAPL that would flow into a well or other recovery point.

- Evaluate the recoverability of the free product (LNAPL).

- Determine the vertical and horizontal distribution of residual product; defined as the LNAPL that remains in the soil pore space but will not flow into a well or other recovery point.

- Characterize the constituents of the LNAPL at various locations on the BROS property and in the adjacent wetlands.

- Estimate the mass of LNAPL above and below the current water table.

- Determine the relative mobility potential of the constituents of the LNAPL.

- Understand the physical (e.g., viscosity, BTU value) and chemical characteristics of the LNAPL in the former Process and Tank Areas and lagoon residuals below and around the excavation limits of the incineration work.

- Determine the vertical and horizontal distribution of the peat layer encountered below the former Process and Tank Areas and at the base of the lagoon excavation.

- Understand the physical, hydrologic, and chemical characteristics of the peat layer beneath the former lagoon, especially its hydraulic conductivity and chlorinated solvent content.

- Determine the vertical and horizontal distribution of the Constituents of Potential Concern (COPCs) in former source areas (Process Area, Tank Area, Lagoon). COPCs include chlorinated solvents (i.e., PCE, TCE) nonchlorinated solvents (BTEX), lead, and PCBs.

- Evaluate the Pepper Building for potential residual sources of contamination.

- Screen for DNAPL below the former Process and Tank Areas and the former lagoon.

Characterization of the secondary sources of contamination associated with the former primary sources of contamination is necessary to evaluate: the risks posed by the site currently and in the future; the reduction in toxicity, mobility, and volume resulting from the treatment of lagoon materials; the probable effectiveness and implementability of potential remedial alternatives; and reasonable restoration timeframes, considering the difficulty of remediating LNAPL (and, if present DNAPL) which is trapped at least in part below the water table.

Objective 3 - Establish the Vertical Distribution and Characteristics of the Fill, Ash and Lime, and Cover Material Layers in the Former Lagoon

Several potential considerations related to the incinerator ash management unit must be evaluated during the Phase 2 RI/FS. The filling of the lagoon influenced hydrogeologic properties associated with ground water flow and surface water runoff in the vicinity of the former lagoon. Prior to the lagoon work, the lower permeability sediments that settled out of the waste stream caused liquid (including stormwater) to accumulate in the lagoon. Over time, this accumulation of water and sediment and the subsequent increase in hydraulic head modified the outward and downward forces throughout the water-bearing zones near the lagoon. The berming of the lagoon provided additional space for water to accumulate and water levels to rise.

With the excavation and filling of the lagoon, the hydrogeologic conditions in and around the lagoon have been altered. Most of the low permeability sediments were removed. The lagoon was filled with sand and ash. The permeability of the sand must be evaluated to assess whether the lagoon influences ground water flow and to model the effectiveness of pump-and-treat remedies relative to flow paths adjacent to lagoon residuals. The permeability of the sand may

vary due to localized differences in grain size and compaction. The permeability of the ash layer must be evaluated to assess whether it impedes surface water infiltration to ground water.

Lime was mixed with ash for metals stabilization during the lagoon work. The Phase 2 RI/FS will include an assessment of whether the surface water infiltrating to ground water and contacting the alkaline lime/ash mixture will influence the relatively acidic ground water in the Little Timber Creek wetlands; and if so, how this will influence the sequestration of COPCs.

Data and Technical Evaluation Needs:

In order to complete the closure of the incinerator ash management unit and determine the hydrology in the former lagoon area, additional data are needed to augment the existing information.

- Detail as-built specifications of the residuals placed into the lagoon during Phase I including the thickness and elevation of each layer placed in the former lagoon and how the thickness varies.

- Determine the physical, chemical, and hydrologic characteristics of the materials and/or layers in the former lagoon.

Objective 4 - Determine the Distribution and Gradients of COPCs Along Potential Exposure Pathways Under Current Site Conditions

The substantial changes in the site conditions would naturally result from the lagoon incineration work and the associated ground water pumping. These changes will have altered the hydrology and influenced the distribution and concentration gradients of COPCs in the vicinity of the former lagoon. The data for the site are at least 5 to 8 years old and several data gaps are now apparent. The data needs to determine current conditions for specific areas of the site are summarized below.

Off-Property Soils (Beyond BROS Property)

Data and Technical Evaluation Needs:

- Determine background soil quality by soil sampling at multiple locations (e.g. peach orchard and southeast of Route I-295).

- Survey the BROS property to determine the precise property boundaries.

- Delineate the vertical and horizontal distribution of site-related constituents which extend beyond the BROS property. This is especially important near Cedar Swamp Road and U.S. Route 130.

Gaventa and Swindell Ponds

Data and Technical Evaluation Needs:

- Complete the evaluation of the distribution of Constituents of Potential Ecological Concern (COPECs) as well as the gradients of COPECs in surface water and sediments in the northwest corner of Gaventa Pond; given the age of some data it is important to confirm the previous analytical results for Swindell Pond.

- Evaluate the hydrologic conditions and interactions between Gaventa and Swindell Ponds, ground water and the Little Timber Creek Swamp.

Little Timber Creek Swamp - Between Interstate Route 295 and U.S. Route 130 and Between U.S. Route 130 and Cedar Swamp Road

Data and Technical Evaluation Needs:

- Wetland delineation.

- Identify the vertical and horizontal distribution of COPECs in sediment.

- Understand the surface water flow pattern or patterns in the swamp.

- Identify and compare the horizontal distribution of COPECs in surface water as related to and compared with sediment concentrations.

- Identification of the key species utilizing the swamp and determination of the assessment endpoints.

- Identify the distribution of key species in relation to surface water and to sediment concentrations.

- Characterize the areas dominated by *Phragmites* which contain residual LNAPL in sediment for evaluation of restoration alternatives as part of the Feasibility Study.

- Identification and characterization of reference areas.

Little Timber Creek Swamp - Between Cedar Swamp Road and the Tide Gate Along Route 44

Data and Technical Evaluation Needs:

- Wetland delineation.

- Identify the vertical and horizontal distribution of COPECs in sediment.

- Identification of the key species utilizing the swamp and determination of the assessment endpoints.

- Evaluate the concentration gradients of COPECs in the downstream direction of Little Timber Creek. Identify the horizontal distribution of COPECs in surface water as related to sediment concentrations.

- Identify the horizontal distribution of key species in relation to surface water and sediment concentrations.

Cedar Swamp - Downstream of the Tide Gate.

Data and Technical Evaluation Needs:

- Wetland delineation.

- Evaluate the presence or absence of COPECs in depositional areas along the drainage channel downstream of the tide gate.

Ground Water - Upper PRM and Recent Alluvium

Data and Technical Evaluation Needs:

- Determine the current concentrations of COPCs representative of ground water quality after the conclusion of the lagoon work and determination of ground water flow near the former lagoon under existing hydrogeologic conditions.

- Vertical and horizontal distribution of COPC beneath Little Timber Creek Swamp.

- Horizontal distribution of COPCs beneath the former lagoon.

- Concentrations of COPCs possibly discharging to surface water in Little Timber Creek Swamp.

- Potential for sediment contamination to mobilize and influence ground water quality during periods when surface water recharges ground water.

- Horizontal distribution of dissolved COPCs in the former Process and Tank Areas.

- Evaluate the potential occurrence of DNAPL below the former Process and Tank Areas and the former lagoon.

Ground Water - Upper Confining Layer

Data and Technical Evaluation Needs:

- Evaluate the vertical and horizontal extent of the strata beneath the former Process and Tank Areas, the former lagoon, the Little Timber Creek Swamp adjacent to the BROS property and to the north of Route 130.

- Determine the concentrations and vertical distribution of COPCs in soils of this confining layer.

Ground Water - Upper Middle PRM

Data and Technical Evaluation Needs:

- Concentrations of COPCs representative of current ground water quality conditions.

- Vertical distribution of COPCs within the aquifer, especially below and near the former lagoon.

- Evaluate the potential occurrence of DNAPL below the former lagoon area.

- Horizontal distribution of COPCs beneath Little Timber Creek Swamp and between Interstate Route 295 and Swedesboro-Paulsboro Road.

Objective 5 - Establish the Degree of Hydraulic Connections Between the Aquifers and Surface Water

Data and Technical Evaluation Needs:

- Evaluate seasonally the flow direction and probable magnitude of flow between Swindell and Gaventa Ponds and the Upper PRM and Upper Middle PRM.

- Evaluate seasonally the flow direction and probable magnitude of flow between the Upper PRM and the Little Timber Creek Swamp.

- Determine the influence of pumping ground water in the Upper PRM on the Little Timber Creek Swamp, the adjacent ponds, and the Upper Middle PRM beneath the former lagoon.

- Determine the influence of pumping ground water in the Upper Middle PRM on the Little Timber Creek Swamp, the adjacent ponds, and the Upper PRM around the former lagoon. The degree of hydraulic interconnection between the Upper PRM and Upper Middle PRM will need to be specifically evaluated near the former lagoon.

These data will also be used in the water budget analysis, fate and transport assessment of COPC, and feasibility study.

Objective 6 - Establish the Hydrogeologic and Chemical Relationship Between the Chemical Leaman Tank Lines (CLTL) Site and BROS site

Data and Technical Evaluation Needs:

- Evaluate the hydrogeology of the CLTL site to determine the interaction, if any, between the two sites and potential effects of the CLTL ground water remedial system on ground water flow and contaminant fate and transport at the BROS site.

- Determine the extent of the clay confining layer between the Upper PRM and Upper Middle PRM in the area between the CLTL property and the BROS property.

- Evaluate the chemical constituents of concern associated with the CLTL site as compared or contrasted to those associated with the BROS site.

- At the direction of the USEPA, evaluate the vertical and horizontal extent of CLTL-related constituents to assess whether potential remedial technologies at the BROS site will influence the remedial action at the CLTL site (for example, through mobilization of contaminants or alteration of extraction system capture zones).

Objective 7 - Assess the Environmental Fate and Transport of COPCs Under Current Site Conditions and Assess the Future Fate and Transport of COPCs

The Phase 2 RI/FS is a retrospective study, meaning the release of contaminants from the BROS waste oil operation occurred primarily in the past and the primary sources of contamination have been removed. Consequently, the mass loading of contaminants into potential exposure pathways has been decreased substantially and will continue to decline in the future. Under such conditions, the most direct way to evaluate the environmental fate and transport of COPC is to measure the concentration trends along exposure pathways over time at various points along concentration gradients of contamination. However, assessment and modeling of various factors that affect the rate of natural attenuation must also be evaluated separately, including: the biological and chemical degradability of the contaminants, the physical and chemical characteristics of the media, and physical characteristics of the geological medium. The data needs identified below relate to completing the fate and transport assessment of COPCs under current and future conditions.

Data and Technical Evaluation Needs:

- Determine if the distribution of site-related constituents in the Upper PRM and Upper Middle PRM is expanding, stable or decreasing.

- Identify the physical and chemical characteristics that impact the evaluation of the natural attenuation mechanisms and processes in various environmental media.

- Estimate the rates of degradation of the organic COPC in various media and in various portions of the site.

- Determine the chemical and biological degradability of the contaminants under the various physical and chemical characteristics present at the site.

- Characterize the mechanisms of sequestration of COPC and identify the adsorptive and exchange capacities of the various media and across the site.

- Determine the physical characteristics of the geological media as necessary to assess and model the environmental fate and transport of the COPC.

- Based upon the results of additional chemical, hydrologic, and stratigraphic evaluations, evaluate the rate of chemical transport in different geologic media encountered below the site using column leaching studies.

Objective 8 - Determine Representative Exposure Point Concentrations and Characterize Potential Receptors

A large amount of data has been generated for the site over the past twenty years. However, to accurately estimate the exposure point concentrations and the risks arising from those concentrations, the exposure point concentrations must be measured in a manner that can be related directly to current or potential future receptors, human or ecological (USEPA, 1998f). Exposure estimates must be established within a realistic range of exposure, where unlikely exposure scenarios are eliminated from consideration consistent with USEPA policy and guidance (USEPA, 1995).

In considering land use and ground water use, Superfund exposure assessments most often classify land use into one of three categories (1) residential, (2) commercial/industrial, and (3) recreational; and ground water use is classified as potable or non-potable use.

In May 1997, the Settling Defendants reached an agreement with the owners of the BROS property that three perpetual deed restrictions in the form of Declaration Restrictive Covenants would be promptly established for the BROS property, which includes the Pepper Building, the former Lagoon and former Process Areas. The deed restrictions are currently in place and properly recorded. The provisions of the restrictions include:

- Future use of the property excludes residential use and limits other uses to non-retail commercial and/or industrial use. These uses are consistent with the use at the time the release of hazardous substances began.

- All subsurface activities (e.g., digging) are prohibited without prior written approval of the USEPA and NJDEP.

- The installation and/or use of any ground water wells at the site is prohibited without prior written approval of the USEPA and the NJDEP.

Beyond the BROS property, ground water use throughout the site is limited because most residents have connected to the municipal water supply which has also been made available to residents near the site. Consequently, the portion of the site beyond the BROS property boundary will be considered a potential future potable supply source but the current use risk assessment will be based on conditions established as part of this scope of work.

Data and Technical Evaluation Needs:

- Identify current and probable future ground water users that have the potential to be exposed to site-related contaminants.

- Determine representative human health risk assessment exposure point concentrations across various portions of the site in a manner consistent with current and future land use and/or water use.

- Identify ground water users and well configurations at the BROS site. Sample local private wells to evaluate the current extent and gradients of site-related COPCs in ground water and to assess representative COPC concentrations at potential receptor wells.

- Determine representative exposure point concentrations for key ecological receptors across various portions of the site.

- Annually evaluate the planned future use of land, especially land development proposals in the vicinity of the site, by contacting the Logan Township Planning Board periodically throughout the duration of the Phase 2 RI/FS.

Objective 9 - Establish a Range of Remedial Alternatives that are Protective of Human Health and the Environment and Conduct Screening of Alternatives

In establishing the NCP-required range of remedial alternatives, several specific factors will be taken into account, including:

- there are various portions of the site where the distribution and composition of contamination varies and where the potential receptors may vary;
- guidance materials on the conventional methods, strategies, and technologies for ground water and volatile organic compounds in soils that are available (USEPA, 1993e; USEPA, 1996c);
- a variety of site-specific factors, such as LNAPL trapped below the water table and DNAPL (if present), may make remediation impracticable by conventional methods and technologies;
- there are potential adverse effects on sensitive ecological environments from some remedial alternatives;
- there are human health risks posed by various remedial alternatives;
- a limited number of site-related constituents pose the majority of the risks in various media and the evaluation will need to consider the costs and benefits of reducing the principal and secondary risk factors;
- the effect of the CLTL remedial activities on the aquifers beneath the BROS Site;
- in Little Timber Creek Swamp, the areas dominated by *Phragmites* and containing elevated concentrations of site-related constituents are recognized at the start as probably requiring remedial action;

- institutional controls that may be developed or are already in place, such as ground water Classification Exception Areas and deed restrictions on the Borelli property;

- detailed evaluation of reasonable restoration times may be necessary in light of site-specific treatment limitations;

- a combination of remedial technologies and options as well as a phased remedial approach may be necessary to further reduce the toxicity, mobility, or volume of the remaining contamination, taking into account the treatment of wastes already completed.

In order to take these factors into account and develop an integrated remedial approach to the site, the data needs identified under the preceding objectives will be iteratively added into the feasibility study components.

Objective 10 - Conduct Relevant Treatability Studies

Based on data needs identified during the development and screening of remedial alternatives, treatability studies may be designed and conducted to reduce the uncertainty of whether some remedial technologies are feasible. Treatability studies will be described in a Technical Memorandum submitted to the USEPA after initiation of the field activities with the objective to complete the studies in time to be included in the FS alternative evaluation and in the Phase 2 RI/FS report.

Objective 11 - Complete the Cultural Resources Survey Requirements

Supplement the Stage 1A Cultural Resource Survey (CRS) to include the entire BROS site and conduct a Stage 1B CRS based on the previously completed Stage 1A CRS and the results of the supplemental Stage 1A CRS.

5.2 Data Quality Objectives

Data Quality Objectives have been developed for the Phase 2 RI/FS based upon the intended uses of the data and a recognition of the matrix complexities and limitations particular to the site. The DQOs were developed within the context of relevant guidance including the *USEPA*

Requirements for Quality Assurance Project Plans for Environmental Data Operations (EPA QA/R-5), the *USEPA Region II CERCLA Quality Assurance Manual*, and the seven step DQO process detailed in the *Guidance for the Data Quality Objectives Process* (EPA QA/G-4). The primary intended uses for RI data are for risk assessment and evaluation of remedial alternatives. Specifically, the DQOs are a measure of the usability of the data for comparison to risk-based remedial action criteria, including PRGs, ARARs and TBCs, and to support the estimation of COPC concentrations at the point of exposure at the BROS site. To achieve these data uses, two separate numeric DQOs have been established for different portions of the site. For the BROS property, the area between I-295 and Route 130 and the portions of Little Timber Creek Swamp west of Route 130 (where significant matrix interference effects are anticipated) the numeric DQOs are approximately 50% of the PRG. The selection of 50% of the PRG is intended to allow for anticipated difficulties in meeting the method detection limit due to matrix interference, while providing a low enough numeric DQO to protect against changes in regulatory standards and potential measurement errors. This approach is consistent with guidance provided in RAGS Part A (USEPA, 1989a), RAGS Part D (USEPA, 1998f) and the *Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997b). For all areas, where matrix interference effects are anticipated to be minimal or absent, the numeric DQOs will be the method detection limit. These numeric DQOs have been selected to provide for a high degree of usable data, given the prior concerns for matrix interferences, while providing a low enough detection limit target to quantify compounds at levels that:

- can be used to assess the distribution of COPCs through gradients;
- may require consideration during the risk assessment;
- allows for revisions to the PRGs at a later time, if warranted.

DQOs for field screening data are established to ensure the safety of site workers and to provide meaningful data for the selection of site characterization samples and the assessment of the representativeness of sampling results. DQOs for field screening, monitoring and field testing and laboratory analytical data are described below. A more detailed discussion of DQOs is provided in the QAPP.

5.2.1 DQOs for Monitoring, Field Screening, and Field Testing

Field measurements will be taken to assist in the selection of soil, ground water and surface water samples. Additionally, organic vapor monitoring will be conducted for health and safety purposes. DQOs for these measurements need to be stringent enough to accurately characterize site conditions to support sample collection activities and be protective of the health and safety of the field team based upon the action levels established in the HASCP.

A photoionization detector (PID) or flame ionization detector (FID) will be used for field screening and air monitoring. The DQO for the PID or FID will be 1.0 part per million (ppm). To achieve this DQO, the PID or FID will be operated and calibrated in accordance with the manufacturers' specifications.

To measure the ferrous iron content in ground water samples at the time of collection HACH field test kits will be used. The DQO for these test kits is 0.2 mg/l (ppm) which is satisfactory for fate and transport analysis, as well as evaluation of ground water remedies. To achieve this DQO the procedures documented in the manufactures' instructions will be followed.

Other field parameters that will be measured for surface water and ground water include pH, Eh, dissolved oxygen (DO), temperature, and specific conductance. The data quality objectives for each parameter is described below:

pH - 0.1 standard unit,
Eh - 1.0 microvolt,
DO - 0.1 ppm,
temperature - 0.1 degrees centigrade, and
specific conductance - 10 microsiemens.

To achieve these DQOs the instruments will be calibrated and operated in accordance with the manufacturer's specifications.

5.2.2 Laboratory Analytical DQOs

Due to the nature of the media and contaminants at the BROS Superfund Site it is likely that minimum detection limits for many analyses are not achievable. This condition has been recognized and the Consent Decree stipulates that the PRPs may develop alternate data quality objectives (ADQOs), subject to approval by the USEPA. The rationale for development of the site-specific ADQOs is provided below.

The ADQOs selected for the site must allow the data to be used for the following purposes:

- site characterization;
- risk assessment;
- evaluating potential remedial alternatives; and
- conceptual engineering design during the FS.

Within the context of the risk assessment and the FS, laboratory data will be used for estimating the volumes and distributions of COPCs through the use of interpolation and extrapolation along gradients. These results will then be used to calculate probable concentrations of exposure (with subsequent comparison to PRGs and other risk-based objectives) and to estimate restoration times for different alternatives.

The ADQOs for the on-site activities established for the risk assessment are the numeric DQOs described above. The numeric DQOs have been established to ensure that representative data are collected for realistic exposure scenarios. The site complexities and matrix interferences associated with analysis of soil, sediment and lagoon residual samples warrant the use of higher numeric ADQOs. These modifications should not impact the usability of the data for risk assessment and remedial alternatives analysis purposes, provided the numeric DQO target of 50 percent of the PRG is met on the majority of samples.

The concerns for matrix interference are most acute for the wetlands samples. As the ecological risk assessment will integrate both quantitative and qualitative methodologies, the numeric DQOs

will provide for the development and interpretation of risk-based remedial action strategies. In the qualitative approach, the results of sediment analyses will be compared to risk-based screening values. Several of these screening values are below the practical quantitation limits of the standard laboratory methods and will necessitate an evaluation of various cleanup procedures to assess the laboratory's ability to achieve the risk-based numeric DQO to the extent practicable given site-specific conditions. These procedures will be performed as part of the Analytical Method Development activities (Section 6.1.2 - Activity 1f). In the quantitative approach, the measurement endpoints selected for the ERA will be evaluated based on comparisons of similar zones on the site to each other and to reference areas. Measurement endpoints are typically numerical expressions of observations that can be statistically compared to a control or reference site to detect adverse responses to site constituents.

To ensure that data quality needs are met and the above objectives are achieved, the proposed numeric DQOs for laboratory analytical methods are 50 percent of the PRGs, with the exception of selected COPCs in ground water that have standards based on the practical limits of quantitation (PQLs). The most stringent numeric DQOs are for residential well sampling based upon risk assessment objectives and the importance of providing accurate data to the property owner. For residential well samples, the numeric DQOs will be the PQLs.

To achieve these numeric DQOs for soils, sediments, surface water and ground water, SW-846 (USEPA, 1997f) and USEPA methods will be used. These methods provide the laboratory with the flexibility to use sample extract cleanup techniques and allow the use of spiking procedures that are not part of the Contract Laboratory Program (CLP) Scope of Work. The use of SW-846 methods are expected to provide the laboratories with the ability to achieve lower detection limits and a higher percentage of usable data. For non-conventional analyses, other published sources such as American Society Testing of Materials (ASTM) methodologies will be used. As detailed in the QAPP, the quality control procedures that will be followed by the laboratory will ensure that the data can be validated using site-specific data validation criteria based upon the USEPA Region 2 data validation criteria. The results for all VOC, SVOC, TAL metals, pesticide and PCB analyses will be reported, to the degree practical, on a CLP Form I with equivalent CLP data

flags. All other analyses will be reported in a format and level of supporting documentation consistent with the applicable data validation criteria.

6.0 PHASE 2 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

The Scope of Work section of the RI Work Plan presents the tasks and subtasks to complete the Phase 2 RI/FS and to fill data gaps identified in Section 5.0. The task designations follow the Statement of Work in the BROS Consent Decree (Appendix E). Some tasks have been broken out into various subtasks. The tasks and subtasks are as follows:

- Task I - Scoping
- Task II - Community Relations
- Task III - Site Characterization
  - Task IIIA - Field Investigation
  - Task IIIB - Data Analysis
  - Task IIIC - Data Management Procedures
  - Task IIID - Site Characterization Deliverables
- Task IV - Identification of Candidate Technologies
- Task V - Treatability Studies
- Task VI - Baseline Risk Assessment
  - Task VIA - Human Health Risk Assessment
  - Task VIB - Ecological Risk Assessment
- Task VII - Remedial Investigation Report
  - Task VIII - Development of Remedial Action Objectives and Screening of Remedial Alternatives
    - Task VIIIA - Development and Screening of Remedial Alternatives
    - Task VIIIB - Conduct and Document Screening Evaluation of Each Alternative
    - Task VIIIC - Presentation of Remedial Action Objectives and Development and Screening of Alternatives
  - Task IX - Feasibility Study Report
    - Task IXA - Detailed Analysis of Alternatives
    - Task IXB - Detailed Analysis Deliverables

Each of these tasks are described in the sections below. The field activities described in the section below will be completed in accordance with the procedures presented in the Field

Operations Plan which consists of the Sampling and Analysis Plan (SAP), the Quality Assurance Project Plan (QAPP), and the Health and Safety Contingency Plan (HASCP). The SAP includes the following:

- sampling objectives;
- samples location and frequency;
- sample designation;
- sampling equipment and procedures; and
- sample handling and analysis.

Consistent with the QAPP, the sampling and other field activities will be performed under the health and safety protocols presented in the site-specific HASCP in order to identify potentially hazardous operations and exposures and prescribe appropriate protective measures. The HASCP also includes a contingency plan to be followed in case of an emergency.

The sampling performed at the site will be designed to meet the DQOs dictated by the intended use of the data generated during the Phase 2 RI. The QAPP presents the quality assurance and quality control (QA/QC) protocols necessary to achieve the required DQOs.

6.1 Task I- Scoping

6.1.1 Overview Of Scoping Process and Influence on Work Plan Development

The scoping process for the Phase 2 RI/FS included the:

- evaluation of the Statement of Work in Appendix E of the Consent Decree (USDC, 1997a);
- evaluation of the extensive files and other background materials on the BROS site;
- evaluation of other relevant background information, such as CLTL site files;
- limited field observations and analysis of existing data to document the need for additional data;
- completion of site visits;
- regular meetings with the BROS Technical Committee to discuss and decide technical strategies and identify data needs; and

- two scoping meetings and subsequent meetings to discuss the scope of work revisions with the USEPA.

The activities completed above were used to refine the primary and secondary objectives and data needs for the Phase 2 RI/FS. The Phase 2 RI/FS scope of work and methodologies, as presented in the Work Plan, the HASCP, the QAPP and the SAP were prepared as part of the scoping process.

6.1.2 Preparatory Activities

Five preparatory activities were identified in the June 24, 1997 draft of the Phase 2 RI/FS Work Plan. These preparatory activities were to be initiated during the Work Plan review period, prior to initiation of the sampling activities:

- Activity 1a - Inspection and Repair of Existing Monitoring Wells;
- Activity 1b - Evaluation of Ground Water Use On and Around the Site;
- Activity 1c - Stage 1B Cultural Resources Survey;
- Activity 1d - Permit Equivalent Requirements; and
- Activity 1e - Obtain Property Access Agreements.
- Activity 1f - Analytical Methods Development

These activities are presented below. The USEPA approved the initiation of preparatory activities 1a through 1e (USEPA, 1997c) and these activities are ongoing. In addition to the five activities that had been previously approved, a new preparatory activity, the development of analytical methods to more address the site-specific concerns for matrix interference (Activity 1f), has been identified and approved by the USEPA. The preparatory activities are described in more detail in the following sections.

Activity 1a - Inspection and Repair of Existing Monitoring Wells

The existing monitoring wells will be inspected to evaluate the usability of monitoring wells for collecting ground water quality samples, measuring water level elevations and monitoring water

level changes during pumping tests. The monitoring well inspection will include an assessment of well integrity; integrity of the protective casing, cap and concrete collar; and the presence of obstructions and/or sediments.

Additional activities that will be conducted during the monitoring well inspection include establishing a measuring point for subsequent depth-to-water measurements and clearly labeling each well with its monitoring well designation to facilitate quick identification during gauging and sampling events.

After the inspection of the monitoring wells is completed, an assessment of the integrity of each well will be conducted. The results of the monitoring well inspection and integrity assessment will be summarized in a Technical Memorandum to the USEPA. The Technical Memorandum will indicate the monitoring wells that require repair, monitoring wells that will be used for ground water measurements and sampling will be redeveloped to evaluate the integrity of well construction, monitoring wells that should be abandoned, and monitoring wells that should be replaced. Any monitoring well or piezometer abandonment will be performed by a New Jersey licensed well driller and completed in accordance with the well abandonment specifications presented in N.J.A.C. 7:9-9.1 et seq., as detailed in Section 6.8 of the SAP.

After the repairs to the monitoring wells have been completed and replacement wells have been installed, the vertical elevation of the existing monitoring wells will be resurveyed to insure that accurate depth-to-water measurements are collected. The points to be surveyed at each location include: the top of the inside casing at the reference mark, top of the protective casing or curb box, and the ground surface adjacent to the well. The results of the survey will be used to update the existing base map early in the project. The updated base map and current ground water potentiometric surface map will be used to refine the siting of new monitoring wells.

Activity 1b - Evaluation of Ground Water Use On and Around the Site

Private water wells on and in the vicinity of the BROS site were identified and sampled by NUS and CH_2M Hill between 1983 and 1993 (NUS, 1984; CH_2M Hill, 1996a). As part of the ROD for

the lagoon work, a public water supply line was brought into the vicinity of the BROS site. Based upon information received from the Pennsgrove Water Supply Company (PWSC), all of the properties in the vicinity of the BROS site are serviced by a public water supply line including the properties on Cedar Swamp and Swedesboro-Paulsboro Roads. However, to the south of Route I-295 several private wells have been identified through a well permit search conducted at the NJDEP Bureau of Water Allocation. In addition, although public water supply service is available in the vicinity of the site, not all of the properties are currently connected to the supply line.

The objective of the ground water use evaluation is to identify existing water wells on and in the vicinity of the BROS site which are currently operational and determine their usage. A mailing will be sent to all private well owners in the vicinity of the BROS site to determine the current status of their water well. A follow up telephone call or visit to each of the properties will be performed to confirm and/or supplement the results of the response to the mailing. If existing private wells are identified, the Township Health Officer will be contacted to determine if additional information is available. The local water purveyors will then be contacted to determine if the property is supplied with a municipal water source.

When the ground water use survey is completed, a proposal will be submitted to the USEPA to provide for the connection of all ground water users which may potentially be exposed to BROS related constituents, consistent with past procedures for municipal supply near the BROS site. In addition, the results of the survey will be provided to the USEPA in a Technical Memorandum which will also identify the need to sample any of the wells, along with a listing of the sampling parameters. The anticipated sampling parameters are identified in Task IIIA, Activity 4a in Section 6.3.1. The method that will be used to sample the private supply wells is presented in the SAP.

Activity 1c - Stage 1B Cultural Resources Survey

A Stage 1A Cultural Resource Survey (CRS) was completed by the USEPA in April 1992. Based on the findings of the Stage 1A CRS, the USEPA recommended that a Stage 1B CRS be completed. The area of the 1992 study was limited to the area between Routes 295 and 130 with

a small area investigated between Route 130 and 44 Because some of the proposed field activities to be performed as part of the Phase 2 RI/FS will occur outside of the area of the 1992 CRS study, and the FS may consider remedial actions in a broader area, the Stage 1A CRS will be expanded to include the entire footprint of the BROS Site (Figure 1).

Upon completion of the Supplemental Stage IA CRS activities, the Stage IB CRS will be initiated in the areas determined to having high potential for significant archaeological or historical features. Roux Associates, Inc., with the assistance of Hunter Research, Inc. submitted a scope of work for the CRS activities (Hunter, 1998) which was subsequently approved (USEPA, 1998a). The Hunter Research, Inc. scope of work is provided (Appendix D). As presented in the scope of work the CRS activities will be performed in accordance with the New Jersey Historic Preservation Office Guidelines for Phase I Archaeological Surveys (1996). Once the required property access agreements are in place, the CRS activities will be initiated. Upon completion of the CRS activities, the CRS report will be prepared for submission to the USEPA.

Activity 1d - Permit Equivalent Requirements

Some of the proposed remedial investigation activities will occur in floodplains, open waters, and jurisdictional wetlands, and would typically require land-use permits. These permits would be obtained by showing that implementation procedures were established to minimize environmental impact. The state and federal land-use permitting requirements and federal regulations and policy regarding permitting for activities on CERCLA sites were reviewed to determine the requirements for implementing the Phase 2 RI and the results of the review are presented below.

The Consent Decree (USDC, 1997a) and the following federal regulations and policy were evaluated to determine permitting requirements for CERCLA sites:

- the NCP, Section 300.400(e) Permit Requirements;
- *USEPA Memorandum on CERCLA Compliance with other Environmental Statutes*, 50 FR 47946, November 20, 1985 (USEPA, 1985a); and

- *USEPA Policy on Floodplains and Wetland Assessments for CERCLA Actions*, Aug. 6, 1985 (USEPA, 1985b).

These documents all indicate that the on-site goals of CERCLA remedial work are to achieve or exceed applicable or relevant federal public health and environmental laws unless specific circumstances exist. Also, in accordance with the NCP and the USEPA's November 20, 1985 memorandum, the application for and receipt of permits is not required for on-site response actions taken under the Fund-financed or enforcement authorities of CERCLA. USEPA's Policy dated August 6, 1985 advises that particular attention be paid to remedial action within wetlands and floodplains and that mitigation requirements be honored.

Based on the direction provided above, it is Roux Associates, Inc.'s intention to implement remedial activities in accordance with applicable federal and state land-use permitting requirements. However, the RI scope of work does not include submission of permit applications to the agencies or receipt of land-use permits or approvals. Moreover, the Consent Decree defines the site as including the areal extent of the contamination relating to the release or threatened release of hazardous substances and all suitable areas in very close proximity to the contamination necessary for implementation of response activities, which includes in its entirety the BROS property where the operations occurred that led to the release of hazardous substances, the area where site-related chemicals are detected in ground water and the area where surface water and sediments contain site-related chemicals above background concentrations (Figure 1). Using this definition, all work will be conducted within the site so that the application for and receipt of permits is not required. Only off-site disposal activities may require permitting. To ensure compliance with permitting requirements, a permit review will be sought, although NJDEP will not issue permits for the work. The permit equivalency requirements of the following programs and agencies will be used during the RI.

Work within jurisdictional wetlands or transitional areas (typically 50 to 150-foot buffers which are off-set from the wetlands boundary) are subject to New Jersey's Freshwater Wetlands Protection Act (N.J.A.C. 7:7A), as New Jersey has assumed full jurisdiction of wetlands

protection from the federal government with the exception of those within 1,000 feet of tidal areas. The placement of borings and wells within these areas will be conducted in accordance with Statewide General Permit GP #14 and the placement of weirs and temporary roads will be conducted in accordance with GP #4, which requires mitigation, if applicable and necessary. As such, the proposed work would require that Statewide General Permits be obtained for work in up to one acre of New Jersey-protected areas. Borings, roadways and weirs are not planned for wetlands under ACOE jurisdiction at this time.

Also, stream encroachment, waterfront development, and soil erosion and sediment control approvals may be required, depending on the final design and location of weirs and temporary roads. These approvals are administered in accordance with the Flood Hazard Area Control Act Rules, (N.J.A.C. 7:13-1.1), Coastal Permit Program Rules, N.J.A.C. 7:7, and New Jersey's Standards for Soil Erosion Sediment Control (N.J.A.C. 2:90-1.1. et seq.).

Activity 1e - Obtaining Property Access

Several activities to be completed during the Phase 2 RI/FS will require off-property access. These include the CRS, soil and ground-water sampling, monitoring well installation, ecological assessments and surveying. The first activity was the completion of a boundary survey of the BROS property, to establish the properties where access will be required. Access to a total of 63 properties is estimated based upon the boundary survey. The access agreement procurement process has already been initiated.

Individual property owners were approached by letter to seek access. The letter contained a property-specific description and rationale of the proposed activities that will require access. Where appropriate, the letter included pictures and descriptions of wells, drill rigs and similar items to provide the property owner with a more complete understanding of the equipment that may be brought to the property. The letter identified an opportunity to meet with representatives of the BROS Technical Committee at the Logan Township Municipal Building to ask questions about the access agreement and the proposed work for their property. This meeting was held on February 4, 1998. In addition, the letter included an offer for an on-property visit to address

specific questions. Copies of materials were provided to USEPA prior to mailing to residents. The access agreement procurement process is continuing.

Activity 1f - Analytical Method Development

The laboratory service firms that have participated in the development of this Work Plan, and who will likely perform the chemical analyses of samples from the BROS site, evaluated potential matrix interference concerns based on the review of past site data. The laboratories were tasked with identifying potential laboratory methods which can reliably achieve detection limits consistent with the numeric DQOs, given the likely matrix interference concerns. Based upon this evaluation, the laboratories proposed that SW-846 methodologies, as opposed to CLP methods, be used and that method development activities be conducted prior to the receipt of site characterization samples. The use of SW-846 methods (USEPA, 1997f) will provide the laboratory with greater flexibility in methodology and cleanup procedures which, in the experience of the laboratories, will allow the laboratories to achieve lower detection limits and a higher percentage usable data that are more consistent with the project DQOs. As provided in more detail in the QAPP, the laboratories will follow SW-846 methods while maintaining consistency with CLP protocols, to the extent practical.

The laboratories will use media from the BROS site to evaluate potential method modifications and cleanup methods for VOC, SVOC and PCB analyses as a means of addressing matrix interferences before site characterization samples are received. The completion of method development activities ahead of the site characterization will provide the laboratories with the ability to perform various trial modifications without exceeding the holding times for characterization samples. Moreover, the early development and approval of revised methods will reduce the likelihood of having to repeat sampling and field activities due to critical RI data being qualified or rejected.

The Analytical Method Development will also include an assessment of different preservation methods for sediments. In earlier versions of the Work Plan, sediment samples were not going to be preserved using either the methanol or sodium bisulfate methods. The use of methanol will

dilute the sample, resulting in higher method detection limits (MDLs). These MDLs will exceed the screening criteria used for the evaluation of sampling results (i.e. 50% of the PRGs as defined in Section 5.2). Due to the predicted density of the sediment and the fixed volume of the sodium bisulfate sampling kits, increased MDLs are also expected with this preservation technique. Moreover, in the experience of the laboratories who will analyze the samples, sediment samples frequently effervesce when preserved with sodium bisulfate; rendering the sample unusable. The benefits of attaining an MDL that meets the project-specific sediment screening criteria and provides data that can be used in decision making are more consistent with the project DQOs than employing field preservation to reduce potential VOC losses during sediment sampling. USEPA has required that sediment samples be preserved, either with methanol or sodium bisulfate. In order to evaluate the potential impacts of these preservation methods, replicate sediment samples will be preserved by three different methods: (1) methanol, (2) sodium bisulfate and (3) ice. The samples will be analyzed and the results compared to assess the attainable MDLs and potential for effervescence using the three preservation techniques.

The Analytical Method Development activity involves the collection of samples of the following complex matrices from the BROS site:

- LNAPL from existing site monitoring wells MW-1A and S-11A (Figure 7);
- peat from proposed boring locations PB-4 and P-24 (Figure 20);
- lagoon residuals/mud wave soils from boring locations L-9A and L-10A (Figure 20);
- two surface water samples from Little Timber Creek at locations FM-1 and FM-2;
- sediments from the *de manifestis* and intermediate zones at LTC-8, LTC-10, LTC-25 and LTC-28 (Figure 26); and
- ground water from monitoring wells S-2A and MW-13A located in the vicinity of the lagoon (Figure 7).

Sample locations will be based on the review of historical site data and field observations at the time of sample collection. Sample collection will be in accordance the procedures set forth in the Sampling and Analysis Plan for the BROS site and will require the use of a drill rig to facilitate the

collection of subsurface soil and peat samples. Any soil boring abandonment will be performed by a New Jersey licensed well driller and completed in accordance with the soil boring abandonment specifications presented in N.J.A.C. 7:9-9.1 et seq., as detailed in Section 6.8 of the SAP.

After the samples are collected, they will be submitted to the laboratory for analysis for VOCs, SVOCs, and PCBs. The laboratory will then evaluate the analytical data quality and determine if sample extract cleanup for SVOCs and PCBs or other method modifications will improve data usability or more effectively achieve DQOs. If the initial analysis of the SVOC and PCB samples indicates that the quantitation limits do not meet the required DQOs, sample extract cleanups will be conducted on each matrix to be analyzed for SVOCs and PCBs to evaluate the effectiveness of the cleanup procedures. The analysis of cleaner extracts requires less dilutions and results in lower quantitation limits. Cleanup methods are not available for VOCs using SW-846 or CLP methodologies. Potential sample extract cleanup methods may include:

- gel permeation chromatography for SVOCs,
- sulfur cleanup for PCBs, and
- sulfuric acid cleanup for PCBs.

If, after cleanup of the SVOC and PCB extracts, the detection limits still do not meet the required DQOs, the laboratory will employ the use of selected ion monitoring (SIM) mass spectrometry. SIM may also be used for VOC analysis if the numeric DQOs can not be achieved for the initial samples. The use of SIM mass spectrometry generally results in a lowering of the detection limits by a factor of ten.

The laboratory will evaluate the effectiveness of using sample extract cleanup methods and SIM analysis and recommend method changes for inclusion in the QAPP. A Technical Memorandum detailing proposed sample extract cleanup methods and method modifications will then be prepared and submitted to the USEPA for review and approval.

The surface water samples collected as part of the analytical method development activities will be collected for PCB analysis. The PCB analyses of surface water samples are proposed to evaluate whether the laboratory can consistently achieve the numerical DQO of 0.007 µg/l which is below the laboratory's standard reporting limit of 0.1 µg/l.

Additional method development activities that will be conducted include an evaluation of the amount of preservative (hydrochloric acid) required to reduce the pH of ground water samples to be analyzed for VOCs to less than two standard units (i.e. pH < 2.0). This task will be accomplished by collecting ground water samples at S-2A and MW-13A and testing the pH of the samples in the field using a pH test strip. If the pH is less than two standard units, the laboratory will be notified that the amount of preservation provided is adequate. If the pH of the sample is greater than two standard units, additional preservative will be added a drop at a time until the pH is reduced to less than two standard units. The laboratory will then be notified of the amount of additional preservative required to achieve the desired pH and this volume will be used for all subsequent ground water sampling events.

6.1.3 Scoping Deliverables

Scoping Deliverables required by the Consent Decree (USDC, 1997a) include a Phase 2 RI/FS Work Plan and Field Operations Plan. The Work Plan contains a summary of existing site data, a description of the physical environmental conditions at the site, detailed descriptions of tasks to be performed, and descriptions of work products to be submitted to the USEPA and is submitted herewith. The Field Operations Plan (FOP) contains a SAP, QAPP, and a HASCP and has been submitted under separate cover. The SAP will ensure that sample collection and analysis activities are conducted in accordance with technically acceptable protocols such that the resulting data meets DQOs. The QAPP will describe the QA/QC protocols that will be followed to ensure that project DQOs will be achieved. The HASCP addresses the protection of health, safety and response to contingencies, which could affect health, safety and the environment during implementation of the Phase 2 RI/FS.

6.2 Task II - Community Relations

Community relations activities will be conducted during the Phase 2 RI/FS in accordance with the Consent Order (USDC, 1997a) and the Community Relations Plan which will be prepared by the USEPA. Although the Community Relations Plan is the responsibility of the USEPA, the BROS Technical Committee has requested to play an active role in the implementation of the community relations activities as stated in their Community Relations Participation Proposal (Roux, 1997).

The BROS Technical Committee proposed to be involved in the following activities:

- reporting to local government officials;
- community relations plan preparation;
- community interviews;
- community relations activities related to property access and private potable well sampling;
- fact sheet preparation;
- local community information repository service;
- public meeting preparation; and
- response to public comments.

The Community Relations Participation Proposal (CRPP) was conditionally approved (USEPA, 1998b) with the minor modifications requested. In addition to some editorial changes, the USEPA required that

- the format and content of the proposed quarterly progress report for local government officials be presented for USEPA's review and comment;

- all documents placed in the proposed community information repository should be approved by the USEPA;

- a public meeting may be scheduled once the revised work plan is reviewed, finalized and approved by the USEPA; and

- the BROS Technical Committee or their representatives must immediately notify the USEPA if any action or event during the Phase 2 RI/FS causes a threat of a release of Waste Material, or an immediate threat to the public health or the environment.

The CRPP was modified and resubmitted to USEPA during the Work Plan review period and subsequently approved (USEPA, 1998c).

Community Relations Activities Related to Private Potable Well Sampling

Even though water supply pipelines have been extended to areas where private potable wells may be affected by site-related contaminants, some private wells may remain in use and should be sampled during the RI/FS (Section 6.1.2). Residents with potable wells will be contacted and arrange for sampling the water from their wells. All activities will be done in consultation with the USEPA. If not already available, a survey requesting relevant well use and construction information will be sent to the residents prior to sampling.

6.3 Task III - Site Characterization

The objectives of the site characterization are outlined in Section 5.0. Site characterization data will be used to support the risk assessment and the FS. The various site characterization activities are described in the following sections.

6.3.1 Task IIIA - Field Investigation

Activity 1 - Water Budget Investigation

Analysis of the water budget in vicinity of the former BROS Lagoon is essential to understanding the fate and transport of COPCs and selecting remedial options for ground water and wetlands. This information will be used to model surface/ground water interactions; assess transport of COPCs; evaluate potential receptors, exposure routes and potential risks and evaluate remedial alternatives.

The objectives of the water budget are to:

- establish water movement (direction and volume) into and through the study areas;
- evaluate surface water/ground water interactions;
- establish aquifer properties including hydraulic conductivity and hydraulic gradients;
- establish stream/wetlands characteristics including seasonal variations, channel morphology, water depths, potential tidal influence, and flow patterns during storm events;
- refine and verify the conceptual site model;
- support the risk assessment, especially the fate and transport assessment; and
- support the evaluation of remedial alternatives.

The water budget study area will be focused between Routes I-295 and 130. However, the regional framework of the water budget will be evaluated through the use of reference data available through the USGS, FEMA, NJDOT, and DRBC; and information developed on the neighboring CLTL site, monitoring points north of U.S. Route 130, and several monitoring points south and east of Route I-295. These data will also be used, in conjunction with field observations, to refine the floodplain models and identify the limits of the 100-year flood across the study area.

The scope of work for evaluating the water budget was developed based upon the methods included in *Planning Hydrology for Constructed Wetlands* (Pierce, 1993) and includes the following activities:

- measurement, over a course of twelve months, of surface water and ground water elevations for each season of the year;

- measurement of precipitation and the effect of precipitation on surface water and ground water elevations and flow rates based on hydrographs constructed from data collected at surface water flow gauging stations;

- obtaining and evaluating monthly precipitation data from 1960 to the present in order to evaluate patterns of precipitation during the waste oil operations and determine the representativeness of the data measured in the Phase 2 RI/FS;

- determination of the interaction between surface water and ground water through the use of staff gauges and clustered wells installed in different strata beneath the site, as well as aquifer pumping tests; and

- analytical evaluation based on site-specific empirical data (modeling).

For each measurement effort, data collection activities will extend over one month to ensure several precipitation events are evaluated during relatively wet and dry times of the year. The integration of RI/FS tasks into the water budget analysis is presented below.

Activity 1a - Meteorological Data Collection

Precipitation and evaporation will be measured to evaluate their influence on surface water and ground water flow. Evapotranspiration rates will either be obtained from a local weather reporting station, if available, or estimated using the Thornwaite method as described in Pierce (1993). For open standing water (e.g. ponds), the evapotranspiration rate will be estimated from evaporation data. Precipitation will be estimated using a tipping bucket variety of precipitation gauge which will contain heating elements to melt and measure the water content of snow and frozen rain, but will be designed to avoid evaporative loss.

Evaporation will be measured using an evaporation gauge that uses a balanced sensor assembly coupled with a standard Class A evaporation pan. The sensor assembly includes a float which rises and falls with the water level in the pan and measures the movement using a potentiometer. The precipitation gauges and evaporation pans will be placed at two locations; one in the Little

Timber Creek Swamp and the other in an open, unshaded area nearby. Both gauges will be situated in an accessible location within 100 feet of the AWTS (a source of electric power). These locations will have vegetative cover and protection from the wind that are similar to the conditions in the broader study area (i.e. separate gauges for both the swampy area between Routes I-295 and 130 and the ponds). As the evaporation pan will be placed outdoors in a representative area of the site, evaporation rates will be actual and will not require correction to wind, temperature or humidity.

The meteorological data will be collected using hourly averages and stored electronically on a data logger. The information stored on the data logger will be downloaded to a portable computer in the field or obtained via modem over a phone line installed at the site trailers. The data will be stored in an electronic database and included as an appendix to the RI report. Seasonal averages will be calculated for all parameters.

The meteorological data collection will be initiated upon implementation of the RI/FS activities and will continue until approximately one month after completion of the aquifer pumping test, at which time the data will be used in the ground water flow model. As such, the data collection activities are planned to extend over a twelve month period, with measurements in each of the four seasons and the data collection in the driest and wettest periods of the year.

Activity 1b - Stream Flow and Hydrograph Evaluation

Surface water elevation data and ground water elevation data from the Upper PRM will be evaluated to determine the relationships between surface water and ground water in Little Timber Creek Swamp and to determine if there is net flow in or out of the system. This data will be used to support the assessment of COPC fate and transport.

Surface water level data will be compared to ground water level data by constructing hydrographs for each monitoring well/staff gauge cluster (Figure 18). Evaluation of the hydrographs will be conducted to determine the relative balance of surface water discharges to ground water or ground water discharges to surface water and the degree of seasonal variations between the

relationships. Net flow data will be evaluated by comparing flow readings from the surface water gauging stations with the hydrographs from monitoring well/staff gauge clusters.

Additional investigations that will be conducted as part of this activity include dye studies to confirm stream flow data and identify preferential flow patterns which will be used to refine surface water and sediment sampling locations. An environmentally safe, non-toxic dye will be introduced into surface water at various locations and allowed to disperse. The dispersal patterns will be observed and mapped over the course of the day. A more detailed description of dye studies is provided in the SAP.

Activity 1c - Water Level Measurements

Surface water and ground water elevation data will be collected throughout a twelve month period to assess variations in ground water/surface water interactions due to seasonal influences. Although the primary focus of this investigation is the Little Timber Creek wetlands, measurement points throughout the site have been established to support RI data evaluation, the risk assessment and the evaluation of remedial alternatives. A conceptual representation of the water level measurement approach is depicted in Figure 17.

The water level measurements will be collected from monitoring wells, staff gauges, well points and surface water flow gauging stations depicted in Figure 18, as summarized below. The elevations of these measuring points will be established by a New Jersey Licensed Surveyor. The water level measurements will be collected daily, on weekdays, for a one-month period during each season. Measurements will be collected over a course of 12 months, to ensure the range of hydraulic conditions are measured. Water level measurements will be conducted as summarized in the SAP. Two significant precipitation events (greater than 1-inch in 24 hours) will be monitored more aggressively to develop stream hydrographs and evaluate the response of the various environmental compartments in the water budget. As noted in the scoping meetings, it is essential that the full range of hydraulic conditions be measured in order to evaluate the response of the wetlands and upper aquifer to ground water pumping remedial alternatives. In addition, to be able to put the year of water budget measurements in the context of average variability (wet

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year, dry year), monthly precipitation records for a location near the site will be acquired and summarized. This analysis will be valuable in predicting the influence of pumping shallow ground water for a several year period which is likely to encounter relatively wet and dry years.

The more intensive measurement periods will be for a short time before, during, and for several days after the significant precipitation event for a total time of at least two weeks and possibly for up to 4 weeks. Selected monitoring points will have pressure transducers installed to monitor the water levels at 15-minute intervals while other points will be measured manually on an hourly basis during daylight hours. The preliminary monitoring points selected to have pressure transducers are MW-22S, MW-25S, MW-29S, WMW-2/SG-2, WMW-3/SG-3, and SG-10. The pressure transducer locations may be adjusted based on the number and type of equipment used and the results of preliminary water level measurements.

In addition to the ground water elevation data collection described above, ground water elevations in all monitoring wells will be measured to evaluate seasonal variability in elevations and flow direction, and to assess the rate of change following precipitation events. All existing and proposed wells will be used for elevation measurements once per quarter. Selected wells will be fitted with water level recorders (pressure transducers integrated with data loggers) to assess the rate of change during and after significant precipitation events.

Surface water elevations in Gaventa Pond, Swindell Pond and Little Timber Creek will be recorded through direct measurement using staff gauges. The staff gauges will be installed on wooden or steel stakes placed through the bottom of the ponds or stream (Figure 18). The gauges will be scaled at an interval of 0.01 feet. The gauges will be situated so they can be easily read from the bank of the stream or pond and will be located in accessible positions, where possible. Six of the staff gauges will be collocated with the wetland monitoring wells described below. Selected staff gauges will be fitted with stilling wells to allow the use of water level recorders when more frequent monitoring is necessary.

Wetlands monitoring wells constructed by alternative techniques suitable for local conditions will be installed in the Little Timber Creek wetlands to measure ground water elevations in the alluvium below the standing water in the wetlands/creek. These data will be used to assess seasonal head differences and discharge/recharge relationships between ground water and surface water. The wetlands monitoring wells will be constructed at two screened intervals. The shallow points will monitor the surface water zone and the deeper point will monitor the top of the Upper PRM aquifer. A detailed description of wetland monitoring well specifications is provided in the SAP. The monitoring well points are designated WMW-1 through WMW-6 and their locations are illustrated on Figure 18.

Surface water flow gauging stations will be located where Little Timber Creek passes through culverts at a location upstream at Route I-295 and downstream at U.S. Route 130 to evaluate stream flow. A portable flow meter capable of monitoring extremely low flow rates (less than 5 centimeters per second) will be used at the storm water culverts to allow for the measurement of surface water flow into and out of the study area based upon water height and velocity. The portable flow meter will be used to collect instantaneous flow measurements at the storm water culverts (similar to grab sampling). For the seasonal water level measurements (i.e. measurements on a daily basis for one month each season) the portable flow meter will be used to obtain three measurements on a daily basis for one month.

During the significant precipitation event measurements (greater than 1-inch, and preferably greater than 2 inches in 24 hours) the portable flow meter will be used to obtain measurements on an hourly basis during day light hours at each of the culvert monitoring points, subject to accessibility. Monitoring of the precipitation event will commence 24 hours prior to the predicted precipitation event and continue until the start of precipitation and 72 hours after precipitation stops or base flow on Little Timber Creek returns to within +/- 10% of the prestorm rate for four consecutive hours. The gauging stations, designated FM-1 through FM-4 will utilize existing culvert structures for flow control to the degree practical in order to minimize disturbance to upgradient areas and to better monitor low flow events. Their design will be refined based on

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input from the New Jersey Department of Transportation, the DRBC and the Federal Emergency Management Agency.

Activity 2 - Soil Investigation

A soils investigation will be completed as part of the Phase 2 RI in a phased approach to identify any remaining sources of contamination and characterize the residual contamination in terms of location and concentration gradients, in order to support the risk assessment and remedial alternative evaluation. The areas targeted for the soils investigation are the background and off-property soils (Activity 2a) and the on-property soils (Activity 2b), which includes the former Process and Storage Tank Area and former Lagoon Area. Soil sampling associated with installation of monitoring wells is described in Activity 4a. The rationale for selecting each soil boring location and the targeted depth of the borings has been summarized (Table 9). All investigation-derived waste generated on the BROS property will be contained, classified and disposed in accordance with applicable regulations. Waste generated off the BROS property will be handled in accordance with the NJDEP *Field Sampling Procedures Manual* (1992) which allows for material to be placed on the ground if it is not contaminated. To determine if an investigation-derived waste is contaminated, it will be analyzed in the field for VOCs using the on-site laboratory, visually inspected and screened for the presence of odors. If the concentrations of VOCs are determined to be below the NJDEP Unrestricted Use Soil Cleanup Criteria (URUSCC) it will be placed on the ground adjacent to where it was generated. The soil sampling methods and the protocols for handling of investigation-derived wastes are presented in more detail in the SAP.

Where practical, deep monitoring wells (proposed in Activity 4a) and deep soil borings (i.e. those that extend to the base of the Upper Middle PRM) will be installed prior to the initiation of other soil investigation activities to provide local stratigraphic information. Phase 3 soil investigation results in the former Process and Tank Areas have been reviewed and boring locations have been situated to complement the USEPA data. The depth and locations of the proposed soil borings may be adjusted based on the findings (stratigraphy and chemical characteristics) of the continuous soil sampling performed during the installation of nearby wells/borings and a review of

any additional results of the Phase 3 investigation. The need to sample beneath secondary source areas was evaluated against the potential for contamination carrydown during sampling. The conclusion was that sampling is necessary in order to ensure the selected remedial alternative is protective and cost-effective. Specific precautions to reduce the spread of contaminants are incorporated into the sampling method.

In general, soil samples collected during Activities 2a and 2b will be obtained from soil borings using a split-spoon sampler or Shelby tube. The soil borings will be drilled using a hollow stem auger drill rig or a mud rotary drill rig. Mud rotary drilling may be required due to running sands encountered below 15 to 20 feet BGS and will be employed when drilling through the former lagoon area and the confining layer between the Upper PRM and the Upper Middle PRM to reduce the potential for carrydown of contaminants. If additional soil sampling is necessary to meet the objectives based on the initial round of soil sampling activities, a second phase of soil sampling would be completed. During the second phase of soil sampling, shallow (less than 20 feet BGS) soil borings will be completed using Geoprobe® direct push equipment. Applicable New Jersey boring abandonment requirements (N.J.A.C. 7:9-9.1 et seq.) will be followed throughout the soils investigation. Specific abandonment procedures are detailed in Section 6.8 of the SAP.

The previous soil sampling for VOCs at the site has not used methanol preservation to preserve the soil samples collected for VOC analysis during the Phase 2 RI. The methanol preservation method is intended to prevent the potential loss of VOCs from the soil sample and will reportedly produce more representative sample concentrations than unpreserved samples. Furthermore, the NJDEP now requires soil samples collected for the analysis of VOCs to be preserved using methanol (N.J.A.C. 7:26E - 2.1(a)4). Therefore, all soil samples collected for VOC analysis will be preserved in the field using methanol, with the exception of those collected for the comparability analysis described below.

Because previous soil samples collected for VOCs were not preserved using methanol, a percentage of collocated samples will be collected without methanol preservation to assess the

comparability of data for site-specific constituents and soil conditions. The percentage of soil samples collected without methanol preservation in the source areas (Former Process Area and Former Lagoon) will be 20% of the samples collected for VOC analysis up to a maximum of 20 samples, and in areas outside of the Source areas, where COPC concentrations are expected to be lower, will be 40% of the samples collected up to a maximum of 50 samples. The specific comparability samples will be determined in the field based upon field screening and sample recovery.

At each boring location, split-spoon soil samples will be collected continuously, in 2-foot intervals, from land surface into the horizon or geologic unit targeted by that boring. The depths of the borings will extend to a minimum of the top of the clay confining layer between the Upper PRM and Upper Middle PRM, or to the depth of unimpacted soil based on visual observation and field screening, except where indicated.

The field screening and sample collection process is summarized in a flow chart (Figure 19). Field screening of soil borings will include measurement of head-space organic vapors using a photoionization detector calibrated to detect chlorinated VOCs, visual observation for staining and sheens, tactile assessment for slipperiness, and classification of soils according to the Burmister method. Field screening will also include the use of an on-site laboratory for NAPL and chemical analyses (VOCs, lead and TPH). The on-site laboratory will be used to document gradients of soil contamination, based upon the results of other screening methods and a comparison to existing data, as a tool in selecting samples for off-site laboratory analyses. As such, chemical analyses using the on-site laboratory will be conducted more frequently for off-property soils and for those distant from former sources than for those in former source areas. The use of the on-site laboratory for chemical analyses of highly contaminated soils will limit the daily throughput of the lab and provide duplicative data when compared to results from the off-site laboratory. NAPL detection screening will include UV fluorescence and hydrophobic dye testing as described in Activity 3.

At least three soil samples from each boring will be collected for off-site laboratory analysis:

- one will be biased to the zone exhibiting the most evidence of contamination based on field screening and visual observation;
- the second will be collected from a depth below the first where field screening indicates substantially less contamination; and
- the third sample will be collected at the base of the boring or at an alternate, shallower, location where field screening indicates lower concentrations of COPCs in order to establish the vertical distribution of COPCs through the use of gradients.

Additional samples may be collected for off-site chemical analyses based upon field conditions and on-site laboratory screening results. For example, additional samples may be collected where NAPL is indicated (See Activity 3 - NAPL Investigations) or to evaluate the vertical distribution of COPCs in the confining layer, in support of the evaluation of remedial alternatives and remediation timeframes. Based upon the current understanding of site conditions, it is estimated that at least one additional sample will be collected in 10 to 15 percent of the borings. The sample selection for laboratory analyses will be flexible to meet the objectives of determining the concentration gradients of the COPCs and additional samples will be collected if warranted.

Activity 2a - Background and Off-Property Soils

Soil samples will be analyzed to determine the concentrations of COPCs from locations off of the BROS property. Background soil samples will be collected to determine the concentrations of COPCs not related to activities historically performed at the BROS property that may be related to natural conditions (e.g., metals in soils) or regional issues (e.g., TPH). Also soil samples will be collected from locations near the BROS property to assess the extent of COPCs from the BROS property (e.g., the swale near U.S. Route 130 and the Peach Orchard).

Background

Two soil samples will be collected at each of six off-property locations during the installation of the following monitoring wells: MW-20D, located to the west of the BROS property; and MW-17D, MW-18D, MW-19D, MW-33D and MW-34D located to the southeast of Route I-295 (Figure 23). The soil samples will be collected from the 0 to 6 inch depth interval and the 18 to 24 inch depth interval and analyzed for the full COPC list of chemical parameters: TCL VOCs, TCL SVOCs, PCBs, and TAL metals. These locations are far enough away from the BROS property that activities on the property would not have contributed COPCs to the surface soil at these background locations. The sampling frequencies and depths are based upon the procedures outlined in N.J.A.C. 7:26E-3.10(a)3.

Swale

LNAPL has been identified in monitoring well MW-13A which is located in the drainage swale along U.S. Route 130. This area will be investigated during the LNAPL investigation (Activity 3) and soil samples will be collected and screened for the presence of LNAPL and geotechnical parameters as described in that section. Proposed soil borings for the swale area are P-30, P-31, P-33, and P-35. The depths of the borings will extend to the top of the clay confining layer between the Upper PRM and Upper Middle PRM (up to a maximum of 40 feet BGS), or to the depth where, based on visual observation, field screening and gradients, the vertical distribution of COPCs can be established. In the northern portions of the BROS property, the confining layer will likely be encountered at a depth of 20 to 25 feet BGS. Three soil samples from each boring will be collected for laboratory analysis, as described previously. Soil samples will be analyzed for TCL VOCs, TCL SVOCs, PCBs, TAL metals, TOC, moisture and pH to evaluate the distribution of COPCs in the swale and the potential for transport to Little Timber Creek.

Peach Orchard

One soil boring will be completed in the peach orchard located to the west of the BROS property (MW-20D). Soil samples will be collected during the installation of MW-20D as described in the background discussion above and during the monitoring well installation. The soil samples from MW-20D will be collected from the surface (0 to 6 and 18 to 24 inch depth intervals) and from

different lithologic units encountered during completion of the boring (e.g., base of Upper PRM and underlying confining layer). The soil samples will be analyzed for TCL VOCs, TCL SVOCs, PCBs and TAL metals.

In addition, an estimated six soil borings will be completed near the Peach Orchard during the Former Process Area and Former Lagoon Area Investigations (Activity 2b). Borings PB-1 and PB-2 will be completed to the west of the Pepper Building to a depth of two feet below the water table. Borings P-20, P-21, L-15B and L-16B will be completed to the west of the former lagoon and will be completed to a depth of 40 feet BGS to the top of the confining clay layer between the Upper PRM and Upper Middle PRM, or to the depth where; based on visual observation, field screening and the use of gradients; the vertical distribution of COPCs can be established. The soil sampling rationale will be the same as that outlined previously (Activity 2). The sampling parameters include chemical and geochemical analyses. The chemical parameters include TCL VOCs, TCL SVOCs, DRO/GRO, PCBs, TPH and TAL metals. The geochemical parameters are TOC, Eh and pH.

Activity 2b - On-Property Soils

Former Process and Storage Tank Area

Thirty soil borings (P-20 through P-44 and PB-1 through PB-5) will be completed in the former Process and Storage Tank Area, the area around and between the Pepper Building and the corner of Gaventa Pond, and the AWTS area including the wetlands immediately to the east (Figure 20). The soil sampling data will supplement existing data, prior observations by Roux Associates, Inc. and the USEPA Phase 3 data (USEPA, 1998), which were used in the development of the scope of work for the process area throughout the RI scoping process. It is anticipated that some of the proposed borings will be completed in locations similar to where the USEPA collected their Phase 3 data, because they are needed for the analysis of additional parameters, especially chlorinated solvents. The soil borings will also provide information that can be used in the evaluation of the potential presence of buried fill in the areas where geophysical anomalies were reported by USEPA contractors (USEPA, 1998). The SAP and HASCP detail procedures to implement in the unlikely event that buried drums or tanks are encountered.

Four zones will be evaluated during the soil investigation in the Former Process Area: surface, vadose, capillary fringe and saturated.

Surface Soil

The USEPA and its contractors placed fill over much of the BROS property as part of the closure of the Phase 1 remedial work. Surface soil samples from two depth intervals (0 to 2 inches BGS and 2 to 12 inches BGS) will be collected from three locations in the Former Process Area in order to document the concentration of COPCs is low in surface soil for use in the human health risk assessment, Task VIA. The surface soil samples will also be used to assess the potential for COPCs in the fill which was placed at the BROS property during regrading. One set of surface soil samples will be collected from boring P-26, near the current location of the office trailers, the second set of samples will be from boring P-34, in the middle of the former tank farm and the location of the third set of samples will be selected in the field.

Vadose Zone

Vadose zone soil samples (i.e. those from the unsaturated zone below the surface soil interval) will be collected from the 30 planned borings to determine the stratigraphy and concentration gradients of the COPCs. The sampling and analytical rationale is described later in this section.

Capillary Fringe Zone

During the completion of the 30 planned soil borings in the Former Process Area, soil samples will be collected from the capillary fringe zone, with a primary objective being the identification of LNAPL. If it is determined that residual product is present, samples will be collected as described in the LNAPL investigation (Activity 3).

Saturated Zone

Saturated zone soil samples will be completed from the 25 P-series borings to determine stratigraphy and to establish the distribution and gradients of COPCs. The sampling and analytical rationale is described below.

Many of the borings to be completed in the former Process Area have been located based on visual observation of the USEPA Phase 3 borings and draft results of the Phase 3 investigation. Some of the borings have been targeted to be installed in areas where LNAPLs are suspected and will serve as a prescreening of the areas for subsequent monitoring well installation to delineate the extent of LNAPL. As with the boring locations proposed within and around the former lagoon, the actual locations may be modified based on conditions encountered in the field. For example, borings proposed in the decommissioned AWTS area may be moved to the closest accessible location if the AWTS equipment will preclude sampling activities. The depths of the borings will extend to the top of the confining layer between the Upper PRM and Upper Middle PRM or a minimum of 40 feet BGS, whichever is encountered first.

Because the Pepper Building was used to store hazardous substances and LNAPL has been identified off the southern end of the building, a soil investigation consisting of five soil borings (PB-1 through PB-5) will be completed around the perimeter of the building to determine if LNAPL may originate from beneath the Pepper Building (Figure 20). The investigation will also entail a visual reconnaissance of the building interior and exterior to establish boring locations. The visual reconnaissance will identify potential areas of discharges to ground water consistent with the *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E-1.8) (e.g., floor drains, discolored, deteriorated or dirt flooring, evidence of spills, stressed vegetation, etc.). The five soil borings proposed will be biased to locations of suspected areas of concern. Additional borings may be completed along the building perimeter if a measurable thickness of free product is encountered in any boring. All five borings will be completed to a depth of two feet below the water table. After completion of the borings around the perimeter and visual reconnaissance inside the building, the need for any additional borings through the building floor will be evaluated, in consultation with the USEPA.

The sampling to be performed in the former Process Area will evaluate the spatial distribution, gradients, and mobility of the COPCs. Delineation of contamination residuals will be consistent with the NJDEP *Technical Requirements for Site Remediation*, applying the NJDEP Restricted Use SCC, for areas within the BROS property and the Unrestricted Use SCC for areas off the

BROS property. Evaluation of the subsurface lithology and COPC concentration gradients will be completed as a result of the soil investigation. Geologic and chemical cross sections will be prepared supporting the evaluation of the fate and transport of COPCs in soil.

Soil samples for geologic logging will be collected continuously in all of the borings from the former Process Area. Soil samples will be inspected and field screened according to the methods outlined previously (Activity 2) with selected samples screened for the presence of LNAPL or DNAPL using the methodology as described in Activity 3a. Three soil samples from each boring will be collected for off-site laboratory analyses:

- one will be biased to a zone exhibiting the most evidence of contamination based on field screening and visual observation;

- the second will be collected from a depth below the first where field screening indicates substantially less evidence of contamination; and

- the third sample will be collected at the base of the boring or at an alternate, shallower, location where field screening indicates lower concentrations of COPCs in order to establish the vertical distribution of COPCs through the use of gradients.

Additional samples may be collected for off-site chemical analyses based upon field conditions and on-site laboratory screening results. For example, additional samples may be collected where NAPL is indicated (See Activity 3 - NAPL Investigations) or to evaluate the vertical distribution of COPCs in the confining layer in support of the evaluation of remedial alternatives and remediation timeframes. The sample selection for laboratory analyses will be flexible to meet the objectives of determining the concentration gradients of the COPCs and additional samples will be collected if warranted.

The sampling parameters include the following parameter groups; chemicals, geochemical, hydrologic, geotechnical and waste classification. The chemical parameters include TCL VOCs, TCL SVOCs, PCBs, TPH, and TAL metals. The chemical characterization of the soils is

intended to establish the distribution of COPCs and assess their solubility and potential mobility, and to determine the presence of metabolites evidencing biological degradation of contaminants. The geochemical parameters (TOC, Eh and pH) will be analyzed in all of the samples to support the evaluation of mobility and partitioning to ground water. The waste classification parameters (TCLP VOCs, SVOCs, metals; total PCBs; ignitability; corrosivity; reactivity; TOX and BTU value) will be analyzed in up to four soil samples to evaluate potential remedial action alternatives for soils.

Shelby tube samples will be collected at eight boring locations and analyzed for geotechnical parameters (permeability, porosity, water content, specific gravity, plastic limits and grain size). The planned Shelby tube sample locations are borings P-20, P-23, P-26, P-28, P-31, P-36, P-41 and P-43 (Figure 20). The Shelby tubes will be collected and analyzed to evaluate the vertical component of hydraulic conductivity from different stratigraphic units. In addition, the data obtained from the Shelby tube analyses will be used in evaluating the vertical component of COPC transport and potential aquifer restoration timeframes during the feasibility study. The depth at which the Shelby tubes are collected will be determined in the field as the depths will correspond to the intervals with the most evidence of contamination based on field screening or to areas where lithologic properties will influence the fate and transport assessment and/or the remedial alternatives analysis. As such, Shelby tube samples will be collected from each of the following stratigraphic units: fill material, Recent sediments, the Upper PRM, peat, and the top of the silt/clay layer overlying the Upper Middle PRM. Based upon Roux Associates, Inc.'s experience in similar formations throughout the Coastal Plain, Shelby tube samples can be collected from the types of strata encountered at the BROS site, although difficulty may be encountered in some coarse sand, stiff clay and gravely zones. Where Shelby tubes cannot be collected due to tube deformation during sample collection (potentially in zones of coarser grained materials) or loss of sample through the bottom of the tube, the ring-line barrel sampling method (modified ASTM Method D 3550) will be employed to collect undisturbed soil samples where a problem is encountered with Shelby tube method, to the extent practicable. This method, which is described in the SAP, uses a series of four six-inch brass rings stacked within a three-inch split-spoon sampler with a sample retention basket which is pressed into the formation by the drill rig. In

addition, in problem strata, the hydraulic properties will be estimated using textural analyses and published literature.

Former Lagoon Area

Soil borings will be completed in the former Lagoon Area to evaluate the distribution and characteristics of the chemical residuals remaining from the lagoon work (Figures 20 and 21). One set of surface soil samples (0 to 2 and 2 to 12 inch depth intervals) will be collected from the lagoon cover (at boring L-4) to assess the concentrations of COPCs in support of the human health risk assessment. Ten soil borings (L-1 through L-8 plus MW-26 and MW-27) will be completed through the former lagoon to assess the configuration and relative thickness of the strata in the former lagoon, the water table location, and any perched water tables; to characterize the ash and sand layers; and to evaluate the characteristics of the residuals which underlie the former lagoon. In addition, eight transects (L-9 through L-16) containing two borings each for a total of 16 borings, will be completed radially around the former edge of the lagoon. The transects will be installed to assess the horizontal extent and characteristics of the lagoon residuals (including the mud wave) along the edge of the former lagoon. The borings will also be completed to evaluate if the clay confining layer above the Upper Middle PRM aquifer is present below the base of the lagoon and to support the analysis for potential DNAPL in both the Upper PRM and the Upper Middle PRM.

All soil borings in the lagoon area will be installed using mud rotary techniques. Split spoon soil samples will be collected continuously in borings from within the former lagoon and around the perimeter of the former lagoon. The actual boring locations and sample collection depths may be modified based on the results of the soil sampling performed during the installation of the deep wells (MW-26D and MW-27D) or modified in the field based on the findings of the initial borings. With the exception of borings L-3, L-4, L-5 and L-6; the total depth of the borings will extend through the peat/mud wave and six feet into the underlying clay layer or silty layer, or to 60 feet BGS-whichever comes first. Based on the available data, the clay layer should be encountered at approximately 40 feet BGS. The soil borings L-3, L-4, L-5 and L-6, and the borings for monitoring wells MW-26D and MW-27D will be extended to the base of the Upper Middle PRM

(estimated to be 120 feet BGS) to provide additional lithologic and chemical characterization data, and to evaluate the potential for NAPL (Activity 3) from beneath the former lagoon.

Soil samples for geologic logging will be collected continuously in all of the borings from the former Lagoon Area. Soil samples will be inspected and field screened according to the methods outlined previously for the former Process Area (Activity 2b) with selected samples screened for the presence of LNAPL or DNAPL using the methodology as described in Activity 3.

Ash

The ash that was stabilized with lime was placed into the excavation of the former lagoon during the lagoon incineration remedial action. Although the ash was reportedly placed above the water table, precipitation infiltration percolating through the ash layer may affect the underlying and downgradient ground water geochemistry. Further, the ash/fill line may extend below the water table in some areas. The lagoon soil borings will be sampled continuously to identify the contact between the ash and backfill. Five soil samples collected from the ash layer encountered in borings L-1, L-2, L-4, L-6 and L-8 will be analyzed for the following geochemical parameters; TOC, Eh, pH, and cation exchange capacity.

Backfill

In addition to the ash, sand from the site (former berms) and off-site sources were used as backfill in the lagoon. In order to evaluate the potential affect of the sand backfill on the ground water geochemistry, five samples will be collected of the sand backfill below the ash layer, from borings L-1, L-2, L-4, L-6 and L-8. The samples will be analyzed for geochemical parameters (TOC, Eh, pH, and cation exchange capacity). One Shelby tube will also be collected from the sand backfill below the ash layer to determine the geotechnical properties of the backfill relative to ground water movement through the former lagoon.

Lagoon Residuals

Up to four samples from each boring will be collected for off-site laboratory analyses. One sample will be collected from the lagoon residuals, the second sample will be collected from the

peat layer, the third sample will be collected from the top of the clay layer or silty strata and the fourth from approximately three feet into the clay/silt layer. For the deeper soil borings (L-3, L-4, L-5 and L-6, and the borings for MW-26D and MW-27) an additional four soil samples will be collected for off-site chemical analyses. One sample will be collected from the top of the Upper Middle PRM just below the clay/silt layer, the second will be collected from the intermediate depth interval exhibiting the evidence of high concentrations of contamination based upon field screening, the third will be collected from the top of the clay layer at the base of the Upper Middle PRM and the fourth will be collected from approximately three feet into the clay layer. Selected samples will be screened for the presence of LNAPL or DNAPL using the methodology as described in Activity 3. Soil samples will also be collected for geochemical, hydrologic and geotechnical analyses (Table 10).

Additional samples may be collected for off-site chemical analyses based upon field conditions and on-site laboratory screening results. For example, additional samples may be collected where NAPL is indicated (See Activity 3 - NAPL Investigations) or to evaluate the vertical distribution of COPCs in the confining layer in order to support the evaluation of remediation timeframes. The sample selection for on-site and off-site laboratory analyses will be flexible to meet the objectives of determining the concentration gradients of the COPCs and additional samples will be collected if warranted.

The lagoon residuals and surrounding fill material in borings L-1 through L-8, MW-26D and MW-27D (below the former lagoon) and in borings L-9 through L-16 will be analyzed for the following chemical groups which include the COPCs: TCL VOCs, TCL SVOCs, PCBs, TPH, and TAL metals. Up to twelve samples from the lagoon residuals, peat and clay will be analyzed for synthetic precipitation leaching procedure (SPLP) VOCs and metals to assess partitioning and restoration timeframes. The SPLP analyses will be used in part, to provide a basis for the selection of samples for subsequent column leaching tests (Section 6.5) and for the assessment of contaminant fate and transport. In particular, the chemical testing, SPLP and permeability results will be used to select a range of stratigraphic units, contaminant types and contaminant concentrations for column leaching tests. Also, the relative difference between SPLP results for

different samples and soil types will provide information that will be used in comparing the relative contributions of dissolved phase constituents from various stratigraphic units.

All of the samples collected from the former lagoon perimeter borings (L-9A through L-16B) and from the underlying peat will also be analyzed for diesel range organics (DRO) and gasoline range organics (GRO). The lagoon residuals and underlying peat and clay samples will also be analyzed for geochemical parameters (TOC, Eh and pH) and six samples will be analyzed for geotechnical parameters (permeability, porosity, water content, specific gravity, plastic limits and grain size) to support the analysis of fate and transport and to evaluate potential restoration timeframes. The Shelby tubes for the geotechnical samples will tentatively be collected from borings L-1, L-2, L-4, L-8, L-10A and L-12A. At least three Shelby tubes will be collected from each of the following, if encountered: the lagoon residuals, the peat layer and the top of the clay or silty layer. Where Shelby tubes cannot be collected due to tube deformation during sample collection (potentially in zones of coarser grained materials) or loss of sample through the bottom of the tube, undisturbed soil core samples will be collected using the ring-line barrel sampling method (modified ASTM Method D 3550). In the event that Shelby tube or ring-line barrel samples can not be collected (i.e. due to compression of the Shelby tube or poor recovery), slug testing of monitoring wells situated in these units will be performed. Where no wells are screened in a specific strata, split spoon samples will be analyzed for density, water content, plastic limits and grain size. As previously discussed in the Former Process and Tank Area, the results of the geotechnical tests will be used to evaluate the vertical component of hydraulic conductivity from these different zones and to assist in the evaluation of the vertical component of COPC transport and potential aquifer restoration timeframes during the feasibility study. These geochemical and geotechnical parameters will be evaluated along with the candidate technologies and preliminary remedial alternatives to decide if additional sampling is warranted.

Activity 3 - NAPL Investigations

LNAPL is a hydrocarbon compound with a density less than water, that exists as a separate, immiscible phase when in contact with water and/or air (USEPA, 1995c). At the BROS site, the LNAPL is a complex mixture of petroleum hydrocarbons, primarily the oil range compounds. LNAPL has been identified in several areas on and surrounding the BROS property (Figure 9):

- along the southwest and east sides of the Pepper Building;
- along the drainage swale along U.S. Route 130 (MW-13A);
- east of the former lagoon (MW-1A, S-11A);
- south and southeast of the former lagoon (Phase 3 soil borings S9W-2, S11AA-2 and S11AA-4);
- along the northern edge of the former lagoon (Phase 3 soil borings B-21, B-36 and B49W-1);
- near the office trailers (Phase 3 soil borings B-9 and R39I-1); and
- in the area of Common Reed (*Phragmites*) in the wetlands adjacent to the BROS property.

LNAPL has been identified on top of the water table near the Pepper Building, along the drainage swale, and east of the former lagoon. Residual LNAPL has been identified in the area of Common Reed (*Phragmites*) in the wetlands. Residual LNAPL has also been identified below the water table along the northern edge of the lagoon and near the office trailers. This distribution is likely the result of the dewatering of the lagoon and surrounding soils which caused LNAPL on the water table to flow by gravity into the previously saturated zone. When pumping stopped and ground water recovered, residual LNAPL was trapped below the water table. The objectives of the LNAPL investigation are to evaluate the quantity, spatial distribution, characteristics and recoverability of the LNAPL on and adjacent to the BROS property. These objectives will be met by performing the following four sub-activities:

- LNAPL physical characterization (Activity 3a);
- NAPL chemical characterization (Activity 3b);

- LNAPL distribution and volume estimates (Activity 3c); and
- LNAPL recoverability analysis (Activity 3d).

No DNAPL is probable at the BROS site, based upon a consideration of the historical waste management processes used at the site, the results of previous investigations and the physical/chemical properties of DNAPL as they behave in the environment (Section 2.5.1.2). Based upon the concentrations of TCE detected in well S-11C, CH_2M Hill monitored for the presence of DNAPL in monitoring wells proximate to S-11C (MW-5B, S-11C, and MW-11B). The assessment involved the collection of ground water samples with a clear plastic bailer and visual observations for DNAPL. Further, DNAPLs were not reported during the 1990 and 1993 ground water sampling events conducted by CH_2M Hill. Concentrations of VOCs reported in CH_2M Hill (1996a) suggest that DNAPL is not present at the BROS site. Based upon these findings and conclusions, no additional investigations were proposed by CH_2M Hill for DNAPL evaluation.

Although DNAPL is not probable, additional investigative methods to detect DNAPL have been incorporated into the Work Plan, at USEPA's request. These investigations are focused to the places where DNAPL would pool and accumulate, where it would wick into low-permeability units, and where it would remain after the passage of free product. The investigation has been developed based upon the USEPA OSWER guidance *Evaluation of the Likelihood of DNAPL Presence at NPL Sites* (USEPA, 1993f and the USEPA Office of Research and Development Research Report *DNAPL Site Evaluation* (USEPA 1993g). The DNAPL investigation includes field tests for the presence of DNAPL (Activity 3e) and the analysis of laboratory data for conditions that suggest the presence of DNAPL (Section 6.3.2). In the event that free DNAPL is detected, chemical characterization of DNAPL will be completed as described in Activity 3b. Based upon all of these studies, a weight of evidence approach will be applied to determine whether DNAPL exists at the BROS site. The scope of any further evaluation of the distribution and volume of DNAPL will be provided in a Technical Memorandum, in the event that DNAPL is detected. The approach outlined in Activity 3c and the previously cited guidance would serve as the basis for these additional investigations, if needed.

Activity 3a - LNAPL Physical Characterization

LNAPL investigations will employ methodologies recommended in various NJDEP, USEPA and private sector reports. LNAPL identification methodologies cited in *Ground Water Issue: Light Nonaqueous Phase Liquids* (USEPA, 1995c), *Ground Water Issue: Dense Nonaqueous Phase Liquids* (USEPA, 1991g), *NJDEP's Field Analysis Manual*, July 1994 (NJDEP, 1994), the NJDEP's *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E) and *A Method for Assessing Residual NAPL Based on Organic Chemical Concentrations in Soil Samples* (Feenstra, et al., 1991) were evaluated in developing the site-specific methods for assessing LNAPL distribution.

Soil borings performed as part of the Soils Investigation will be used to initially evaluate the spatial distribution of LNAPL. Soil samples in which LNAPL is suspected (based upon historical results, PID/FID measurements, staining, visual appearance and slipperiness) will be field screened using a hydrophobic dye test (NJDEP, 1994). In addition, supplemental soil borings will be completed using a Geoprobe® to better define the extent of LNAPL. The Geoprobe® boring locations will be targeted to establish the distribution of LNAPL identified in the soils investigation and will be used only to assess LNAPL on, and immediately below, the water table. Should the observations of LNAPL distribution from the initial soil borings indicate that, deeper investigations (i.e. beyond the practical limits of the Geoprobe) are required to establish the vertical extent of LNAPL, hollow-stem auger or mud rotary borings will be installed. Updates on the findings and the scope of additional sampling will be provided to USEPA at the monthly meetings. Applicable New Jersey boring abandonment requirements (N.J.A.C. 7:9-9.1 et seq.) will be followed throughout the NAPL investigation. Specific abandonment procedures are detailed in Section 6.8 of the SAP.

Data collection will include the information needed to characterize likely LNAPL mobility based upon the calculation of the theoretical pore-water concentration of organics in ground water as outlined in Feenstra et al. (1991). Soil samples collected from strata that are similar to those where LNAPL are encountered will be analyzed for TOC, bulk density, and porosity; site-specific soil/water distribution coefficients (K_d) will be calculated using published values for octanol/water

partitioning coefficients. Where appropriate, soil borings will be converted into monitoring wells to evaluate the presence of LNAPL and to assess actual thickness (Activity 3d). If LNAPL is observed, samples of the material will be collected for chemical characterization (Activity 3b).

Activity 3b - NAPL Chemical Characterization

Samples of the NAPL will be collected for analysis to determine constituent concentrations, define fate and transport-related characteristics, and provide information on potential remedial action alternatives. As LNAPL may exist below the water table (Section 2.5.1.2), LNAPL and DNAPL will be distinguished based upon the relative abundance of constituents (e.g. chlorinated versus nonchlorinated hydrocarbons, DRO/GRO components) and the specific gravity of the separate-phase NAPL.

Samples will be collected from each different type of NAPL encountered based on color (e.g., black, clear), apparent viscosity (e.g., thick, thin) and depth interval encountered. A primary characterization objective is to assess the relative hydrocarbon fractions (e.g. aromatics, PAHs, isoparrafins, chlorinated VOCs) that make up the NAPL as these characteristics are directly related to solubility, adsorption, mobility and recoverability and will be used in the risk assessment and to evaluate remediation timeframes and remedial alternatives effectiveness. The analytical parameters which the NAPL will be analyzed for are: specific gravity; API gravity; viscosity; DRO; GRO; PCBs and lead. NAPL samples and soil samples containing suspected NAPL, if present, will also be analyzed for VOCs.

Soil samples containing NAPL will be analyzed using the SPLP for VOCs and metals to evaluate the partitioning, probable restoration timeframes, and possible design of treatability studies. The SPLP analyses will be used to provide a basis for the selection of samples for subsequent column leaching tests (Section 6.5) and for the assessment of contaminant fate and transport. In particular, the chemical testing, SPLP and permeability results will be used to select a range of stratigraphic units, contaminant types and contaminant concentrations for column leaching tests. Also, the relative difference between SPLP results for different samples will provide information

that will be used in comparing the relative contributions of residual NAPL to the dissolved phase constituents from various stratigraphic units

Activity 3c - LNAPL Distribution and Volume Estimates

Based on the results of Activities 3a and 3b the spatial distribution and volume of the different types of LNAPL will be estimated. The NAPL identified in soil boring logs, results of LNAPL screening, and LNAPL identified in monitoring wells will be used to prepare cross sections illustrating the distribution of LNAPL relative to ground water and stratigraphic units. Once the distribution of LNAPL has been determined, the porosity of the soils will be used to calculate the estimated volume of the free product LNAPL and residual LNAPL.

Activity 3d - Recoverability Analysis

Monitoring wells in which LNAPL is detected, historically MW-1A, MW-13A, S-11A and in the "USGS" monitoring well near the Pepper Building, will be evaluated to determine the thickness of the product in the well using a bail down test (USEPA, 1996d; Hughes et al, 1988). The baildown test methodology used to calculate the actual thickness of free product is presented in the SAP.

Product baildown tests will be conducted monthly for up to six months, in order to evaluate the variability in bail down results and to assess at what rate LNAPL will continue to move into the well. After at least three rounds of data have been collected, the potential for total fluids recoverability testing and/or pilot testing of NAPL recovery will be assessed. Total fluids recoverability testing would entail the removal of several well volumes of ground water and LNAPL, with subsequent monitoring of LNAPL recovery over time (typically up to one week). Potential pilot tests may include passive bailers, peat wicks, routine bailing and/or the installation of a recovery well and skimmer pump. Supplemental recoverability investigations will be presented in the Treatability Study Work Plan or in a Technical Memorandum, if warranted.

Activity 3e - DNAPL Investigations

DNAPL investigations are focused on the places where DNAPL would pool and accumulate, where it would wick into low-permeability units and where residual DNAPL would remain after free product had moved through an area. The investigation has been developed based upon the USEPA OSWER guidance *Evaluation of the Likelihood of DNAPL Presence at NPL Sites* (USEPA, 1993f and the USEPA Office of Research and Development Research Report *DNAPL Site Evaluation* (USEPA 1993g). An assessment of historical data coupled with the conceptual model describing DNAPL fate and transport (Section 2.5.1.2) was used to develop the scope of DNAPL investigations. These investigations include a variety of site characterization methodologies, as listed below, and data analysis methodologies as described in Section 6.3.2.

- Installation of soil borings (Activity 2) and monitoring well pilot holes (Activity 4) with the collection of continuous split-spoon soil samples from the Upper PRM and Upper Middle PRM in the former Process and Tank area and the former Lagoon area. Soil samples will be collected from the immediately above and within low permeability units to assess the potential for accumulation and wicking of DNAPL. Based upon screening in the field (Figure 19), soil samples will be evaluated for DNAPL using fluorescent and hydrophobic dye screening and laboratory analysis.

- Installation and sampling of monitoring wells to the base of the Upper PRM aquifer to assess vertical gradients of VOC concentrations.

- Installation and sampling of monitoring wells to the base of the Upper Middle PRM aquifer to screen for free-DNAPL and assess vertical gradients of VOC concentrations.

- Collection of pre-purge samples of stagnant water from the bottom of wells S-3C, S-11C, MW-4D, MW-5B, MW-21D, MW-22D, MW-23D, MW-26D and MW-27D using clear plastic, bottom-loading bailers to screen for the presence of DNAPL using a hydrophobic dye test.

- Collection of ground water samples using the USEPA Region 2 Low Stress (Low Flow) sampling procedure and analysis of ground water samples for VOCs (Activity 4). (As detailed in the SAP, if DNAPL is encountered and sampled, a minimum 24 hour waiting period will be observed prior to ground water sampling.

Activity 4 - Ground Water Investigation

In order to complete a thorough evaluation of the range of alternatives required by the NCP, the ground water investigation is designed to supplement the existing data and meet the data needs as described in Section 5.1. These include:

- determining the distribution of LNAPL;
- investigation for the presence of DNAPL;
- establishing the distribution and gradients of COPCs in the Upper PRM, especially beneath the wetlands;
- establishing the distribution and gradients of COPCs in the Upper Middle PRM, especially south and east of Route I-295;
- evaluating the characteristics of the Upper PRM and Upper Middle PRM aquifer;
- evaluating the temporal changes in the site hydrology and ground water quality;
- evaluating the fate and transport of COPCs, especially the natural attenuation processes;
- direct measurement of chemical concentrations at potential exposure points; and
- obtaining treatability and geochemical data to support the FS.

Activity 4a - Ground Water Quality Evaluation

There are currently 55 monitoring wells and five piezometers installed on and around the BROS property. The Phase 2 RI activities will include the installation of 45 additional wells on and around the site (Figures 18, 22 and 23). The rationale for selecting each well location and the screened interval for the proposed well has been summarized (Table 11). The actual locations of the monitoring wells will be determined based on field screening activities, results of preceding investigatory activities and limitations based on property access. The typical monitoring well construction will be consistent with the New Jersey monitoring well specifications (N.J.S.A. 58:4A-4.1 et seq.). All of the monitoring wells that will be installed below a confining layer (e.g., clay layer between Upper PRM and Upper Middle PRM) will be constructed using a double cased monitoring well in accordance with New Jersey monitoring well specifications. The 45 wells include six pairs of wetlands monitoring wells, WMW-1 through WMW-6, which will be installed in the Little Timber Creek wetlands to evaluate the distribution of COPCs and the hydrology of the wetlands and underlying ground water.

Consistent with USEPA's recommendation, slotted augers will be used at five locations to collect field screening data to evaluate the vertical distribution of COPCs and select the screen interval for proposed monitoring wells in the area southeast of I-295. However, the use of slotted augers on a grid basis in Little Timber Creek Swamp between Route 130 and I-295, and on a more extensive basis in the area southeast of I-295, was evaluated and found to be impractical for the following reasons.

- The use of slotted augers in Little Timber Creek Swamp and wetlands southeast of I-295 will require substantial cutting of vegetation and filling of wetlands to construct access roads to obtain drill rig access. Construction of the access roads would remove keystone species, fragment the wetlands, alter surface water hydrology and could result in a substantial shift in structure and function of the wetlands.

- The wetlands permit equivalency process would require demonstration that there is no alternative method of data collection that could avoid the loss of wetland habitat and disruption of wetlands from an extensive pattern of ground water study, as would be used

for the slotted auger screening. The mitigation alternative process would reveal that a reasonable alternative does exist, the generally accepted approach of using properly spaced wells and soil borings to extrapolate and interpolate data and develop COPC gradients. The planned monitoring well array is designed to provide information to establish the gradients of contamination along the direction of chemical transport in an iterative manner over an extended period of time.

- Significant resistance to access from property owners located southeast of I-295 has been encountered. An expansion of field activities will exacerbate these problems. Property owner concerns are commonly related to the intensive agricultural use of this area and include the following.

  - Large scale permanent damage to top soil via compaction will result from drill rig access in agricultural areas.

  - The wide spread use of pesticides in the agricultural areas southeast of I-295 creates logistical concerns due to the relatively short notice that the property owners will be able to give prior to application, the extended time periods required prior to re-entry into the area; and unnecessary health and safety risks to the field personnel.

  - The property uses provide little room for access without permanent damage to orchards and seasonal crops.

- Excessive amounts of investigation-derived waste will be generated as a result of installing borings on a grid pattern.

USEPA had recommended the slotted auger screening, in large part, to maximize the probability of placing wells in strata containing maximum concentrations, based upon a concern for spatial variability in ground water quality. Predominant concerns were the detection of the center of contaminant mass and the potential for a fingering nature of concentration distribution. The proposed investigative methods are designed to address the RI/FS data needs and technical

objectives with respect to characterization of ground water quality. The study includes a combination of:

- monitoring wells screened at multiple depth intervals along the axis of ground water movement from source areas;
- monitoring wells screened at multiple depth intervals perpendicular to the axis of ground water movement from source areas;
- continuous logging and screening of soil samples during monitoring well installation;
- provisions for an iterative ground water study that will include additional monitoring wells if needed based upon the initial phases of the investigation; and
- the use of slotted augers in the area south of I-295, within the limitations outlined previously, to select the screened interval for monitoring wells in this area.

Moreover, the concern with the fingering nature of concentration distribution in some granular aquifers is more pronounced when the source is a small point and the duration of travel time is a few years. At the BROS Site, the source was approximately 15 acres (lagoon and process area) and the source has been present for over 30 years and does not fit the model where fingering is likely (Cherry, 1998). Therefore, the proposed approach is a reasonable balance of relevant considerations designed to achieve the RI/FS objectives.

Slotted augers will be used to field screen the vertical extent of COPCs in ground water at five monitoring well locations (MW-17D, MW-18D, MW-19D, MW-33D and MW-34D). The first step of the process will be to install a pilot boring at one location (MW-18D) to the top of the confining unit between the Upper Middle and Lower Middle PRM in order to evaluate stratigraphy southeast of I-295. The stratigraphy will be evaluated by collecting continuous split spoon samples from the surface to the confining layer between the Upper Middle and Lower

Middle PRM and performing a natural gamma log on the boring to verify visual observations. The pilot boring will then be abandoned by a New Jersey licensed well driller in accordance with the well abandonment specifications presented in N.J.A.C. 7:9-9.1 et seq., as detailed in Section 6.8 of the SAP . Information from the pilot boring will be compared to existing site data to develop stratigraphic interpretations of the Upper PRM and Upper Middle PRM southeast of I-295. Because the additional monitoring wells south of Route I-295 are along strike and the stratigraphy in this area is consistent (as was seen in MW-14B through MW-16B) the depth of the confining layers can accurately be extrapolated laterally when combined with existing site stratigraphic information. Therefore, only one pilot boring is proposed in this series of wells.

For the other slotted auger locations (MW-17D, MW-19D, MW-33D and MW-34D), the screened interval will be established based upon the ground water screening results from the slotted augers and a natural gamma log performed through the slotted auger system. These field results will be compared to the stratigraphic information from the pilot boring at MW-18D (i.e. classification of split spoon samples, natural gamma logging, ground water quality data) and the existing stratigraphic data from other wells throughout the study area to determine the optimum location for the screened interval at MW-17D, MW-19D, MW-33D and MW-34D. The USEPA will be verbally apprised of the findings and recommended well intervals.

For the Upper PRM, the slotted augers will be advanced to a point five feet below the water table and a sample will be collected for VOCs and analyzed by a field laboratory using SW-846 methodology. Additional samples will be collected for field laboratory testing in the Upper PRM at 20 foot intervals, until the confining layer at the base of the Upper PRM is reached. Based upon an evaluation of the stratigraphic data developed from the pilot boring at MW-18 in conjunction with existing stratigraphic information, additional samples will also be collected from preferential contaminant flow paths, as characterized by higher permeability strata (e.g. coarse sand, gravel). One additional sample will be collected from the interval just above the confining layer between the Upper PRM and Upper Middle PRM and analyzed for VOCs by the field laboratory. The proposed sampling interval will ensure that samples are collected from at least two locations within the middle of the aquifer, in addition to those collected at the top and the

bottom. This frequency is consistent with the conceptual model for contaminant transport through ground water and will provide enough data points to interpret the vertical distribution of VOCs through the aquifer.

Once the sample has been collected from the base of the Upper PRM, the auger string will be removed, the bore hole will be reamed with a larger diameter auger and a surface casing will be installed into the confining layer and grouted in place to facilitate sampling in the Upper Middle PRM and the eventual installation of a deep monitoring well.

The well casing will be allowed to set for two days prior to the collection of ground water field screening samples from the Upper Middle PRM. The slotted auger will be advanced five feet below the confining unit and a ground water sample will be collected and analyzed for VOCs by the field laboratory. Subsequent ground-water samples will be collected from the Upper Middle PRM at 20 feet intervals and analyzed for VOCs by the field laboratory. One additional ground-water sample will be collected from the five foot interval above the confining layer between the Upper Middle and Lower Middle PRM and analyzed for VOCs by the field laboratory. As with the plan for the Upper PRM, additional samples will also be collected from preferential contaminant flow paths which are identified during the pilot boring for MW-18. As described previously, natural gamma logs will be performed through the slotted auger to provide information on stratigraphy. The gamma logs will be compared to logs from the pilot boring at MW-18 and records for other wells installed at the site.

After the field laboratory results and natural gamma logs are received, they will be evaluated and the screen zone for the well will be selected. The deep monitoring well will be completed through the surface casing in accordance with the proceedings outlined in the SAP and the drill rig will be mobilized to the next location and the procedure will be repeated. A more detailed description of the slotted auger drilling process is provided in the SAP. Ground-water sampling procedures for samples collected from the slotted augers are also provided in the SAP.

Investigation-Derived Waste

All investigation-derived waste generated on the BROS property will be contained, classified and disposed in accordance with applicable regulations. Waste generated off the BROS property will be handled in accordance with the NJDEP *Field Sampling Procedures Manual (1992)* which allows for material to be placed on the ground if it is not contaminated. To determine if an investigation-derived waste (e.g., drilling mud, development water, and purge water) is contaminated, it will be analyzed in the field for VOCs using the on-site laboratory or containerized and analyzed using the off site laboratory. If the concentrations of VOCs are determined to be below the NJDEP GWQC it will be placed on the ground adjacent to the well from which it was generated, provided the property owner does not have any objection. The protocols for handling of investigation-derived wastes are presented in more detail in the SAP.

Monitoring Well Installation

Ground-water monitoring wells will be installed in the wetlands, the Upper PRM aquifer (including the fill material adjacent to the former lagoon) and the Upper Middle PRM aquifer to provide ground water elevation and ground water quality information. The construction specifications of the proposed monitoring wells have been summarized (Table 12). As stipulated by the USEPA at the scoping meetings, With the exception of the wells installed for the aquifer pumping tests (Activity 4b) all monitoring wells will be constructed of two inch stainless steel screens (10 feet for regular monitoring wells and two feet for the wetlands monitoring wells) and risers. USEPA stipulated the use of stainless steel monitoring wells at the scoping meetings and stated that no variations would be considered. Continuous split-spoon soil samples will be collected during installation of the monitoring wells to evaluate the presence of COPCs, evaluate physical parameters of the aquifer and determine the geology as discussed in the sections below. Soil samples will also be collected from any confining layers encountered to determine their geotechnical properties and the concentrations of COPCs. The geotechnical properties and COPC distribution within the silt/clay layer will be used to evaluate the potential restoration times under various remedial alternatives as continuing sources to the overlying and underlying aquifers.

Wetlands Monitoring Wells

The six pairs of monitoring wells constructed by alternative methods and installed in Little Timber Creek Swamp (WMW-1 through WMW-6) will be used to evaluate the distribution of COPCs, the flux of COPCs between surface water and ground water, and the vertical hydraulic gradient in the wetlands and the top of the Upper PRM. Surface water samples will be collected concurrently with the ground water samples from points adjacent to these wells to evaluate the relative concentrations of COPCs in the different medium.

The six pairs of wetlands monitoring wells in Little Timber Creek Swamp (WMW-1 through WMW-6) will include two wells which screen different two-foot intervals immediately below the surface of the wetland sediments. The shallower of these wells will have the top of its screen set from one foot below the ground surface (excluding the loose muck layer at the surface) to three feet BGS. The deeper well of the pair will have the top of its screen set one foot below the bottom of the screen of the shallower wells. The well pairs will provide information on the seasonal vertical gradients of COPCs and hydraulic gradients within the wetlands ground water and will be used in the water budget investigation (Activity 1).

Proposed Upper PRM Monitoring Wells

Sixteen monitoring wells will be installed into the Upper PRM, fill material or Little Timber Creek Swamp (Figures 18 and 22). The monitoring wells proposed to be installed in the Upper PRM are intended to fill the data gaps in the existing network of Upper PRM wells. The data obtained from the proposed Upper PRM monitoring wells will also be used to calibrate the ground water flow model; and for the fate and transport assessment, the risk assessment and the feasibility study.

Monitoring wells MW-24S, MW-25S, MW-28S, MW-29S, MW-30S, MW-31S, MW-32S will be screened across the water table to evaluate the presence of LNAPL and concentrations of COPCs in former source areas. These monitoring wells will be completed to a depth of approximately seven feet below the water table with a screen extending three feet above the water table, allowing free product to enter into the well, if present. Depending upon the time of year that the

wells are installed, the screened interval may need to modified to ensure that the screen bridges the water table and that any free LNAPL can enter the well. The current projected schedule (Section 8.0) for installation of these wells is late Spring to early Summer 1999. Monitoring wells MW-26S and MW-27S will be installed in the backfill in the lagoon (i.e., below the ash layer) to evaluate the ground water quality and hydrology within the lagoon. These two wells will be used in conjunction with other existing and proposed wells to provide data for establishing vertical and horizontal gradients under current conditions.

Monitoring wells MW-21S and MW-22S will be installed across the water table in the Little Timber Creek wetlands to the southeast of the former lagoon. These wells differ from the wetlands monitoring well pairs (WMW-1 through WMW-6) in that they have ten feet of screen. These wells will be used to assess the Upper PRM and alluvium between U.S. Route 130 and Route I-295 in order to characterize the spatial distribution and gradients of COPCs. These wells will also be a part of the water budget investigation (Activity 1) and will provide information on the interaction between the surrounding wetlands and the Upper PRM and Upper Middle PRM (as monitored in well clusters).

Monitoring well MW-23S will be installed across the water table to the south of the former lagoon, immediately adjacent to Swindell Pond. MW-23S is also part of a well cluster including MW-23I and MW-23D which both monitor the Upper Middle PRM. MW-23S will be used in conjunction with staff gauges and MW-23I and MW-23D as a monitoring point to evaluate the hydraulic interaction between the pond, the adjacent Upper PRM aquifer and the Upper Middle PRM below.

Two monitoring wells, MW-21L and MW-22L, will be installed to the base of the Upper PRM (screened above the clay confining unit) and are designated with an "L". In conjunction with the results of soil investigations (Activity 2), these wells will provide data to evaluate the vertical and horizontal distribution of COPCs in the Upper PRM downgradient of the BROS property. Other wells screened near the base of the Upper PRM aquifer (MW-11A(D), MW-14A, MW15A, MW-16A) will also be sampled during the Phase 2 RI. Additional L-series wells will be installed near

the former lagoon and former Process Area if warranted based upon the results of the soils investigation. The locations and rationale for these additional wells will be provided in a Technical Memorandum for USEPA review and approval.

Two monitoring wells will be installed through the base of the ponds to the south and southwest of the former BROS Lagoon. The monitoring wells will be used to characterize the surface water/ground water relationship between the ponds and the underlying Upper PRM aquifer. The wells will also be used to calibrate the ground water modeling efforts. Monitoring well PZ-1 will be installed in the northeast corner of Gaventa Pond and monitoring well PZ-2 will be installed in the northern portion of Swindell Pond. Both monitoring wells will be completed with ten feet of screen with the top of the screen set five feet below the bottom of the pond. Stainless steel casing and riser will stick up a minimum of three feet above the surface of the pond. The objective is to monitor the Upper PRM immediately below the ponds. If the Upper PRM is either too thin to monitor or not present, the screen will be set into the clay or silt layer below the pond or into the top of the Upper Middle PRM, whichever is encountered. Continuous soil samples will be collected during the installation of these wells. A more detailed description of the well installation procedures is presented in the SAP. Shelby tube or ring-line barrel samples will be collected from near the top of these well borings (i.e. near the base of the pond) for geotechnical analysis. The purpose of the geotechnical analysis is to provide information for the evaluation of the flow between the pond and ground water. The soil core sample will be collected from the first encountered firm material (as opposed to loose sediment near the base of the pond) which is expected to be fine-grained residuals accumulated from the sand mining operations, which included hydraulic dredging and working of the sand. Geotechnical data from this depth interval should provide a basis for the evaluation of hydraulic conductivity from the zone of lowest transmissivity.

Sampling of soils in the monitoring well clusters (MW-21, MW-22, MW-23, MW-26, and MW-27) will be completed in the deepest well, which will be installed first, to evaluate the subsurface conditions at each location. Based on the soil sampling performed in the deep well, the screened interval for each shallower monitoring well in the cluster will be determined and the wells will be

installed without soil sampling. Additional sampling from shallower wells could be conducted if recovery volumes or site conditions warrant.

Soil samples from the shallow monitoring wells (MW-24S, MW-25S and MW-28S through MW-32S) will be collected continuously from the surface to the bottom of the borehole. Since some of these wells will be used to evaluate the presence of LNAPL, these wells will be screened across the water table (Activity 3). Two soil samples will be collected for off-site laboratory analysis during each well installation; a sample from the six-inch interval above the water table and one from a greater depth to evaluate vertical contamination gradients. The location of this deeper sample will be based upon field screening as described in Activity 2 and Figure 22. The soil samples will be analyzed for VOCs, SVOCs, metals and PCBs (Table 10). If possible, Shelby tube or ring-line barrel samples will be collected during the installation of selected monitoring wells (preliminarily MW-24S, MW-25S and MW-31S) to obtain geotechnical information on the aquifer to supplement the geotechnical data obtained during the results of the soils investigation. As previously discussed in Activity 2a, the results of the geotechnical tests will be used to evaluate the vertical component of hydraulic conductivity as well as to assist with the evaluation of the COPC transport, and potential aquifer restoration timeframes during the feasibility study. If undisturbed soil core samples cannot be collected, hydraulic parameters of the formation will be estimated based on existing slug test results and other sources of hydraulic data for the same unit/strata.

Proposed Upper-Middle PRM Monitoring Wells

Seventeen monitoring wells will be installed into the Upper Middle PRM (Figure 23). All wells will be double cased and installed using mud rotary techniques. The monitoring wells will be screened at the top and bottom of the aquifer to assess the vertical distribution of COPCs. Five of the proposed monitoring wells will be installed in the upper portion of the Upper Middle PRM aquifer and are designated with an "I" for intermediate depth. Twelve of the proposed monitoring wells will be installed at the base of the Upper Middle PRM aquifer and are designated with a "D" for deep. The proposed monitoring wells in the Upper Middle PRM will supplement the existing network of Upper Middle PRM wells to evaluate the horizontal and vertical distribution of

COPCs downgradient of the source areas, and to evaluate the vertical hydraulic gradients. The data obtained from the monitoring wells will also be used to calibrate the ground water flow model, Task IIIB, Activity 4.

Monitoring wells MW-21I, MW-21D, MW-22I and MW-22D will be installed in Little Timber Creek wetlands to the southeast of the former lagoon to monitor the Upper Middle PRM aquifer. Monitoring wells MW-23I and MW-23D will be located adjacent to the northern end of Swindell Pond in a cluster with shallow well MW-23S to monitor the top and base of the Upper Middle PRM aquifer, respectively. These wells will be used to evaluate the surface water/ground water relationship between Swindell Pond and the Upper Middle PRM aquifer and to support the evaluation of the vertical distribution of COPCs. They will also be used to calibrate the ground water flow model.

Monitoring well MW-4D will be installed to screen for the presence of DNAPL at the base of the Upper Middle PRM and to asses the vertical and lateral distribution of COPCs immediately to the south of the former lagoon.

Monitoring wells MW-26I, MW-26D, MW-27I, and MW-27D will be installed through the former lagoon and will monitor the Upper Middle PRM aquifer. These wells will be installed in two separate clusters containing MW-26S, MW-26I, MW-26D and MW-27S, MW-27I, MW-27D, respectively. During installation of these monitoring wells, soil samples will be collected for geotechnical parameters to confirm the presence of a low permeability silt and clay layer below the base of the former lagoon. Soil samples collected near the base of the former lagoon, approximately 25 to 35 feet BGS, will be field screened for the presence of NAPL (see Activities 2b and 3). Monitoring wells MW-26D and MW-27D will monitor the base of the Upper Middle PRM. Monitoring wells MW-26I and MW-27I will be installed in the Upper Middle PRM just below the lagoon. The monitoring wells in the Upper Middle PRM aquifer installed below the former BROS Lagoon will be used to screen for the potential presence of DNAPL; to evaluate vertical and horizontal ground water quality trends; and to evaluate the hydraulic relationships

between the ground water in the former lagoon, Gaventa Pond and the Upper Middle PRM aquifer.

Monitoring wells MW-17D, MW-18D, MW-19D, MW-33D and MW-34D will be installed to the south of Route I-295 to delineate the horizontal extent of the contaminants south of Route I-295. Through the use of slotted auger screening of ground water, information will also be collected on the vertical distribution of COPCs in this area. The screen interval for these wells will also be defined using the slotted auger data and natural gamma logs. Elevated concentrations of VOCs were detected in monitoring well MW-10B located along the Route I-295 right-of-way. However, the closest set of wells in the Upper Middle PRM in a downgradient direction, (MW-14B, MW-15B, and MW-16B) are located over 1,500 feet to the southeast and either had no VOCs detected or trace concentrations of VOCs (1 ppb of toluene and xylene) detected which may not be related to the BROS site. Access agreements will be required for these off-property wells prior to installation. Therefore, the locations of these wells will be adjusted to accommodate the land uses of the local property owners and allow for easy access for drilling equipment and future sampling events.

The location of MW-17D and MW-19D have been selected to identify the downgradient lateral boundaries of COPCs in the Upper Middle PRM. MW-18D has been cited along the downgradient axis of the distribution of COPCs. MW-33D and MW-34D will straddle MW-18D to provide additional data to establish the horizontal gradient of contaminants, if present. It is Roux Associates, Inc.'s professional opinion that the vertical and lateral extent of COPCs in the Upper Middle PRM downgradient of Route I-295 can be delineated using these five wells through a combination of direct measurements, stratigraphic interpretation, slotted auger screening, analysis of gradients of COPCs, and modeling, for the following reasons:

- the source of the ground water COPCs is an old source, greater than 25 years old with sufficient time for significant advective transport;

- the source of the ground water contamination was a large area (> 15 acres of lagoon and process areas);

- the use of slotted auger screening coupled with on-site laboratory analysis and natural gamma logging will provide information that can be used to refine the locations of subsequent sampling points;

- the wells are widely spaced apart in order to straddle the flanks of the COPC distribution and evaluate the potential for differential flow through portions of the aquifer; and

- due to the large source area, extended duration of release and transport, relatively broad width of COPC distribution along Interstate 295 and the relatively homogeneous nature of the Upper Middle PRM (CH_2M Hill, 1996a), highly discrete fingering of the COPC distribution would not be predicted.

Because the determination of the lateral extent of COPCs in the Upper Middle PRM is a primary objective of the Phase 2 RI/FS, the field schedule has been structured so that the slotted auger investigations and the installation of wells MW-17, MW-18, MW-19, MW-33 and MW-34 will be conducted early in the project to allow for rapid sampling and installation of additional wells, if warranted. These monitoring wells will be sampled two weeks after development with analysis for VOCs on a rapid turnaround basis. If the analysis of the ground water quality from these monitoring wells suggests that additional locations are necessary, they will be proposed in a Technical Memorandum.

One monitoring well proposed to monitor the base of the Upper Middle PRM, MW-20D, will be installed to the west of the former BROS Lagoon in the orchard north of Gaventa Pond. Analytical results for the distribution of ground water COPCs from this well will be used to characterize the ground water quality to the western edge of the site and will be compared with data from nearby wells on the CLTL site. It will also provide information on the upgradient conditions for the use in ground water flow model calibration.

For those wells where slotted auger screening will not be employed, soil samples will be collected during monitoring well installation and analyzed for VOCs using the on-site laboratory to provide advance data prior to ground water sampling. During installation of these monitoring wells, soil

samples will be collected continuously in the deepest well in each cluster (MW-4D, MW-21D, MW-22D, MW-23D, MW-26D and MW-27D). For individual deep wells (i.e. those not in a well cluster) soil samples will be collected continuously the entire depth with the exception of the monitoring wells installed to the south of Route I-295 (MW-17D, MW-19D, MW-33D, and MW-34D). Because these wells will be installed using slotted auger techniques, continuous split spoon samples will be collected at only one boring location. A pilot boring will be completed at the MW-18D locations which will include continuous soil sampling and geophysical logging prior to completion of the well. This will provide important stratigraphic information for completion of wells MW-17D, MW-19D, MW-33D and MW-34D which will be installed laterally from MW-18D.

Soil samples will be collected for field screening (Figure 20) and off-site laboratory analysis. Up to five soil samples from each of the deep monitoring wells will be collected for off-site chemical analyses for VOCs, SVOCs, metals and PCBs (Table 10) with the exception of the monitoring wells installed to the south of Route I-295 from which ground-water grab samples will be collected through the screened augers at 20 foot intervals and analyzed for VOCs using a field laboratory. In the deep wells in which soil samples will be collected, one sample will be collected from the base of the Upper PRM, one from the top of the Upper Middle PRM just below the clay/silt layer, the third will be collected from the intermediate depth interval exhibiting the greatest evidence of contamination based upon field screening, the fourth will be collected from the top of the clay layer at the base of the Upper Middle PRM and the fifth will be collected from approximately three feet into the clay layer. Selected samples will be screened for the presence of LNAPL or DNAPL using the methodology as described in Activity 3a. Soil samples will also be collected for geochemical, hydrologic and geotechnical analyses (Table 10).

Physical and Chemical Analysis

The physical characteristics of the Upper PRM and Upper Middle PRM and the confining layer between the two units will be evaluated to determine the aquifer and confining layer characteristics.

If possible, Shelby tube or ring-line barrel samples will be collected during monitoring well installation to obtain geotechnical information about the aquifer and confining layer vertical hydraulic conductivity which will be used in the fate and transport assessment and the FS. If, due to the physical nature of the aquifer, undisturbed soil samples cannot be collected from the proposed screen zone, a slug test will be performed to estimate aquifer hydraulic conductivity. The geotechnical parameters include porosity, water content, specific gravity, plastic limits, grain size and permeability. As numerous Shelby tube samples will be collected during the soils investigation (Activity 2), collection of monitoring well-specific soil cores in the Upper PRM will be limited to samples near the screened zones for three monitoring wells (preliminarily MW-24S, MW-25S and MW-31S) and from confining layers. For the Upper Middle PRM wells, Shelby tube or ring-line barrel samples will be collected near the screened interval for each well. Additional soil cores may be collected based upon the observations of stratigraphic units in the field.

Chemical, as well as geotechnical, samples will be collected from intervals which exhibit evidence of visual staining and/or VOCs based on field screening, and at stratigraphic changes. The stratigraphy changes which will be targeted for sampling include the peat layer, the top of the confining layer between the Upper PRM and Upper Middle PRM, from within the same confining layer (to determine penetration of COPCs), below the confining layer (if evidence of VOCs is detected), and the top of the confining layer between the Upper Middle PRM and Lower Middle PRM.

Natural gamma borehole geophysical logs will be completed in all twelve of the deep monitoring wells (MW-4D, MW-17D, MW-18D, MW-19D, MW-20D, MW-21D, MW-22D, MW-23D, MW-26D, MW-27D, MW-33D and MW-34D). Pilot borings will be logged in monitoring wells MW-18D, MW-20D, MW-21D and MW-22D so that the clay confining unit between the Upper PRM and Upper Middle PRM can be identified and the screens of the shallower wells can be accurately installed. Natural gamma logs will be completed within the slotted augers at MW-17D, MW-19D, MW-33D and MW-34D to aid in the selection of the screen zone. The remainder of the wells will be logged after completion of the deep wells. The natural gamma logs will detect

clay and silt zones based on their increased natural radioactivity compared to the clean sands which dominate the PRM aquifers. The fine grained units can be correlated between monitoring wells based on the profile of the logs. Numerous previously installed monitoring wells were logged for natural gamma (CH_2M Hill, 1996) which will be used for correlation of stratigraphic units. Based on comparison of the boring logs and geophysical logs, stratigraphic fence diagrams will be created that will refine the interpretation of the geology below the BROS site.

Ground Water Sampling and Analysis

The ground water quality evaluations are intended to address the following data needs:

- determine the gradients of COPC concentrations in the Upper PRM and the Upper Middle PRM aquifers under current site conditions;
- evaluate the temporal changes in ground water quality since the conclusion of the lagoon work; and
- evaluate the geochemical parameters and contaminant degradation products in support of contaminant fate and transport assessments.

Multiple rounds of ground water sampling and analysis are proposed for the Phase 2 RI/FS. Quarterly sampling of selected wells will be conducted throughout the RI/FS. The objectives of the quarterly sampling efforts are listed below.

- Through a sampling of selected existing wells early in the RI process, verify the existing ground water quality data to support the selection of well locations for the Phase 2 RI. Monitoring well sampling was last conducted in 1993, the detection of low concentrations of VOCs in MW- 14B along Swedesboro-Paulsboro Road has not been confirmed.
- Evaluate the effectiveness of source removal activities through an assessment of concentration trends over time. No ground water sampling has been done since the lagoon incineration remedial action was concluded.

- Assess natural attenuation of COPCs through an analysis of concentration trends - horizontally, vertically, and through time (e.g., increasing, steady-state, or decreasing). In addition, geochemical parameters and COPC degradation product trends will be measured and considered.

Prior to the first, third and fourth ground water sampling events, water levels in all site monitoring wells and select CLTL monitoring wells within 1,500 feet of the BROS site will be gauged. This data will be used to construct ground water flow maps, evaluate hydrogeologic relationships between the BROS site and CLTL site, and to support ground water modeling efforts documented in Activity 4b, which is described below. The wells to be gauged, their locations and the ground water gauging procedures are provided in the SAP.

Prior to the second sampling event, the water level elevations in all BROS site monitoring wells and an expanded suite of CLTL monitoring wells will be gauged. The CLTL wells to be included in this gauging round will be selected based on the following:

- well construction;
- the condition of the monitoring wells;
- CLTL treatment system design; and
- access issues.

The CLTL wells to be included in this second round of gauging and the rationale for selecting these wells will be provided in a Technical Memorandum to the USEPA.

The initial round of ground water sampling will be performed prior to the installation of new monitoring wells to evaluate the current ground water quality. During the initial round of ground water sampling, the following 42 monitoring wells will be sampled: all 30 of the "MW" series wells, S-1A, S-1B, S-1C, S-2A, S-2C, S-3A, S-3C, S-4, S-6, S-11A, S-11C, EPA-107 and EPA-108.

The second round of ground water sampling will take place after the new wells have been installed. During the second round of ground water sampling all of the new wells will be sampled plus the following existing monitoring wells: MW-1A, MW-5B, MW-7A, MW-8A, MW-8B, MW-10B, MW-11B, S-2C, S-3C, S-11A, S-11C, MW-13A and MW-14B. The specific wells that will be sampled in the second round may be modified, subject to USEPA approval, based upon the results of the first round of sampling.

During the third and subsequent rounds of quarterly ground water sampling the existing wells sampled in the second round plus the following new monitoring wells will be included in the quarterly monitoring program; MW-18D, MW-20D, MW-21D, MW-22D, MW-23D, MW-24S, MW-25S, MW-33 and MW-34 (Figure 24). The intermediate zone (L-series and I-series) wells which will be included in the quarterly monitoring program will be determined after the initial sampling of the wells. Specific analytical parameters and frequencies of analysis have been summarized (Table 13). Changes in the quarterly monitoring program will be identified in a Technical Memorandum for USEPA approval.

All of the monitoring wells sampled will be purged and sampled using the March 20, 1998 Region II Low Flow/Low Stress Sampling Protocol (USEPA, 1998h). However, all previous ground water sampling was performed using traditional purge and sampling methods. Because of this change in methodology, a comparability analysis of data obtained using both methods will be performed. The objective of the comparability analysis is to establish the trends between historical and new ground water quality data to facilitate the evaluation of the influence of the lagoon work and the COPC concentration changes associated with natural attenuation, which will provide data for the prediction of spatial and temporal changes in ground water quality. The collection of a minimum of three rounds is proposed to establish a mean and standard deviation for assessment of comparability so that chemical concentrations measured using traditional sampling methods can be compared to future results from use of the Low Flow/Low Stress Sampling Protocol .

For the comparability analysis, the following monitoring wells will be purged and sampled using traditional methods in addition to being purged and sampled using low flow/low stress techniques:

- For the first sampling event: S-11C, MW-5B, MW-7A, MW-8A, MW-8B, MW-10B, MW-11B and MW-14B.

- For the second and third round sampling events: the monitoring wells listed above for the first round plus the following new monitoring wells: MW-18D, MW-20D, MW-21D, MW-22D, MW-23D, MW-24S, MW-25S, MW-29S, MW-33D and MW-34D.

- For subsequent rounds: a maximum of 30% of the wells or ten of the wells listed for the second and third rounds, whichever is less, if needed based upon the results of the prior rounds.

Low flow purge methods will be used first, then traditional purge sampling will be conducted as described in the SAP.

As previously discussed in Activity 1b of the preparatory activities (Section 6.1.2) private water supply wells in the vicinity of the BROS site may be sampled if those wells are possibly within the horizontal extent of site-related COPCs or in the immediate downgradient vicinity. The results of the ground water use survey will be presented to the USEPA in a Technical Memorandum. The Technical Memorandum will identify any wells proposed for sampling and the sampling parameters. Currently, it is anticipated that the sampling parameters will include TCL VOCs using the current drinking water analytical method (EPA 500 series), to assure that the method detection limits are below the applicable federal and state MCLs. In addition, ground water from supply wells within 0.5 miles of the BROS property will also be analyzed for TCL-SVOCs and TAL metals if these constituents are likely to be present based upon the well location and ground water quality data available at the time.

After the installation of the new monitoring wells has been completed, the wells will be sampled for COPCs as well as geochemical parameters. Ground water from all of the monitoring wells

will be analyzed for the following chemical parameters: TCL VOCs, TCL SVOCs, base neutral/extractables only, TAL metals. The following general chemistry parameters will be analyzed to evaluate the fate and transport of COPCs in ground water as described in Section 6.3.2: TDS, TSS, alkalinity, TOC, sulfate, chloride, nitrate, ammonia, silica, orthophosphate, sulfide, nitrite, COD, TKN, hardness, organic acids, methane, ethene and ethane. The following field chemistry parameters will be analyzed: pH, specific conductivity, Eh, dissolved oxygen (DO), ferrous iron, temperature, carbon dioxide and hydrogen sulfide. For the first round of sampling, the wells will be analyzed for the full TCL SVOC scan as the acid extractable portion of the SVOC analysis may identify compounds that include degradation products of the source material COPCs. New monitoring wells MW-26S, MW-26I, MW-26D, MW-27S, MW-27I, MW-27D and MW-29S, and existing wells MW-1A and S-11A are located close to the former lagoon and will also be analyzed for dissolved metals due to the potential for fine particulates associated with the ash/lime layer in the former lagoon. Additionally, pre-purge samples of stagnant water will be collected from the bottom of wells S-3C, S-11C, MW-4D MW-5B, MW-21L, MW-21D, MW-22L, MW-22D, MW-23D, MW-26D and MW-27D using clear plastic, bottom-loading bailers to screen for the presence of DNAPL using a hydrophobic dye test.

Activity 4b - Aquifer Testing

Aquifer testing of both the Upper PRM and Upper Middle PRM aquifers will be performed with the following objectives:

- calculate the aquifers properties;
- determine the hydraulic connection and interaction between the Upper PRM and the Upper Middle PRM aquifers;
- assess the efficacy of pumping for containment purposes;
- further assess the hydraulic gradients beneath the former lagoon;

- assess the potential for ground water extraction to affect the neighboring wetlands adjacent to the BROS property;

- evaluate the feasibility of ground water extraction as a remedial alternative, including an evaluation of the affect of pumping on the local and regional water budget (including ground water extraction at the CLTL site);

- provide the information needed to evaluate the volumes of ground water withdrawal needed for hydraulic control of the areas with residual LNAPL on the BROS property; and

- evaluate the potential for aquifer clean up.

Prior to final design and implementation of the aquifer tests, the RI data collected to date will be evaluated, including any recently available data from the neighboring CLTL site. This information will be used to redefine the optimum design of pumping and monitoring wells, pumping rates and to assess the potential effects on the neighboring wetlands. The preliminary pumping well locations are midway between MW-1A and S-2C along the edge of the former lagoon for the Upper PRM test and near S-11C for the Upper Middle PRM test. The specific pumping well locations, water level measurement locations, chemical sampling approach and specific water management procedures will be detailed in a Technical Memorandum for USEPA approval.

A large volume of water will be generated during the pumping tests and current ground water quality data is needed to evaluate management options. Although water management procedures will be detailed in the Technical Memorandum; preliminarily, the discharge from the tests will be managed using high capacity storage tanks and tanker trucks for off-site disposal. The number of tanker trucks and the capacity of on-site storage will be established based upon the projected pumping rates and the estimated time for travel to and from the disposal facility, including off-loading and waste approval time. The likely disposal location for aquifer test waters is the DuPont facility, located in Deepwater, New Jersey. The RCRA-permitted DuPont facility specializes in the management of aqueous waste streams and is located within 15 miles of the

BROS site. Assuming a 200-gallon per minute pumping rate and a projected turnaround of two hours (which will allow a safety factor for delays in off-loading and acceptance) the volume of water generated in two hours will be 24,000 gallons. Based upon this volume, six 5,000-gallon capacity tankers are needed on a continuous basis throughout the aquifer tests to transport water to the DuPont facility. Temporary high capacity storage tanks (e.g. 20,000-gallon baker tanks) may also be used to provide additional storage capacity and a safety margin in the event of delays at the disposal facility. The use of on-site treatment has been considered, but will likely be precluded by the costs, permitability and the known complexity of meeting discharge limitations associated with Little Timber Creek. The timing of the pumping tests will be during the driest period of the year (September) to evaluate the extent and magnitude of any impact to the wetlands during the most limiting time of the year for the wetland plants.

Both pumping tests (Upper PRM and Upper Middle PRM) will be performed on wells located in the vicinity of the former lagoon. This location is near the highest VOC concentrations in ground water proximate to the potential areas of LNAPL and near the wetlands. As such, the aquifer tests will provide valuable information on the effects of extraction on the secondary source area and on the neighboring wetlands and ponds.

Existing monitoring points will be utilized during the pumping tests where appropriate. The pumping wells will be ten-inches in diameter and will be screened across the entire thickness of the aquifer, approximately 25 to 30 feet for the Upper PRM pumping well and 40 to 50 feet for the Upper Middle PRM well. The pumping wells will be constructed with carbon steel casing and stainless steel continuous wire-wound screen. The screen slot size will be selected based upon a review of the results of a sieve analyses of sediments in the aquifers collected during the monitoring well installation.

To the degree practical, the monitoring points for obtaining drawdown data in response to pumping of the wells will include existing and proposed monitoring wells in both the Upper PRM and Upper Middle PRM in the immediate vicinity of the pumping wells. In accordance with the

New Jersey Geological Survey recommendations for aquifer test monitoring points (NJGS, 1992), the monitoring points will include the following:

- a stilling tube inside the pumping well casing to monitor drawdown in the pumping well;
- a 1-inch diameter PVC stilling tube in the gravel pack outside of the pumping well casing to measure well loss across the screen and well efficiency;
- a 2-inch diameter PVC piezometer installed approximately 10 feet from the pumping well;
- two 2-inch diameter PVC piezometers installed 90 degrees apart (one downgradient and one cross-gradient) with respect to the pumping well at distances from the pumping well equal to approximately 1.5 times the saturated thickness; and
- an existing or proposed monitoring well located at a distance of approximately five times the saturated thickness from the pumping well.

All piezometers will have ten foot screens located approximately mid-point with respect to the pumping well screen, unless otherwise noted.

For the pumping test of the Upper PRM aquifer, an additional 2-inch diameter PVC piezometer will be installed approximately ten feet from the pumping well. The screened interval for this piezometer will be at the top of the Upper Middle PRM aquifer in order to measure vertical gradients across the confining clay unit and estimate vertical leakage under pumping conditions. This piezometer will be installed in a double cased borehole. This piezometer will be installed in a cluster with the 2-inch piezometer screened in the Upper PRM aquifer, and situated ten feet from the pumping well. If an existing well can be used, this piezometer will not be required.

For the pumping test of the Upper Middle PRM aquifer, two additional 2-inch diameter PVC piezometers will be installed approximately ten feet from the pumping well. The screened interval

for one piezometer will be the base of the Upper PRM aquifer and for the second will be the top of the Lower Middle PRM aquifer. These piezometers will be used to measure vertical gradients across the confining clay units and estimate vertical leakage under pumping conditions. The deeper piezometer will be installed in a triple cased borehole. These piezometers will be installed in a cluster with the 2-inch piezometer screened in the Upper Middle PRM aquifer, and located ten feet from the pumping well. If existing wells can be used, these piezometers will not be required.

Well points and staff gauges in the Little Timber Creek wetlands and piezometers and staff gauges in Gaventa and Swindell Ponds will also be monitored during the aquifer tests. In conjunction with ground water elevation data, the water level data from the well points, piezometers and staff gauges in the wetlands and ponds will be used to establish the relationship between surface water and ground water in the Upper PRM aquifer. In addition, depending on the location on the Upper PRM pumping well with respect to Swindell Pond, additional monitoring points may be located between the pond and the Upper PRM pumping well. These points will be monitored to measure horizontal gradients across the pond side banks under pumping conditions as a means of assessing the potential for leakage.

Each aquifer test will consist of two phases: a step-drawdown test to determine the specific capacity of the well and approximate pumping capacity; and a 48-hour constant rate pumping test to evaluate the radius of influence and calculate the aquifer properties.

A background test will be performed prior to the performance of the step-drawdown test. Water levels in selected monitoring wells and the pumping wells, barometric pressure and precipitation will be measured over a 72-hour period to evaluate background conditions. A synoptic round of water levels will be collected from selected nearby monitoring points and automatic water level measuring data loggers will be installed into the pumping well, both 2-inch PVC piezometers and two additional monitoring points (e.g. wells, piezometers, temporary well points in Little Timber Creek wetlands) closest to the pumping well and within the anticipated zone of influence of the pump test. In addition, a data logger will be installed in the background well. The water levels in

these points will be monitored continuously for 72 hours to evaluate the effects of barometric pressure changes, tidal fluctuations and precipitation. The location of the background well, which will be situated in the same aquifer as the pumping well at a distance beyond the predicted radius of influence for the pumping well, will be selected based upon the location of the pumping well and will be identified in the Technical Memorandum detailing the aquifer test protocols. Although an attempt will be made to identify a well within 0.5 miles of the BROS site, one possible location for background water-level monitoring is a USGS well cluster located at the intersection of Swedesboro and Tomlin Station Roads approximately two miles east of the BROS property. The well cluster consists of Upper, Middle and Lower PRM monitoring wells. This well was used as the background well for the aquifer tests at the CLTL site. The data loggers will start recording pre-test data approximately 72 hours prior to and during the step-drawdown test and prior to and during the constant rate pump test until the water levels have recovered to 90 percent of their pre-test values. The discharge rate of the pumping well during the test will be measured using an in-line flowmeter with a direct read gauge and checked manually throughout the test. Proof of calibration for the flow meter will be presented to the USEPA prior to conducting the aquifer tests.

The pumping rate for the 48-hour constant rate pumping test will be selected based on the results of step drawdown test. Based upon a review of the pumping test data from the CLTL site, pumping rates of between 150 and 200 gallons per minute will likely be employed for both aquifers (Ground Water Associates, 1997). Additionally, data obtained from the nearby monitoring points and the background well will be evaluated to ensure the selected monitoring points are adequate for the constant rate pumping test. A round of water levels will be collected prior to starting the pump test and data loggers will be installed in select monitoring wells. The pumping test will commence for 48 hours at which time the pumping well will be turned off and recovery data will be collected until water levels have recovered to 95% of their pre-test values. Flow rate from the pumping well will be monitored as described above and barometric pressure will be recorded on a continuous basis throughout the course of the pumping tests. Precipitation will also be measured over the course of the pumping test.

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Activity 5 - Surface Water and Sediment Quality Evaluation

Surface water and soil/sediment samples will be collected from Gaventa Pond, Swindell Pond, Little Timber Creek and associated wetlands, the swale along U.S. Route 130, and north of Route 44 to major depositional areas downstream of the tide gate. The primary objectives of this portion of the field investigation are to map those areas where LNAPL residuals remain, establish concentration gradients extending out from these areas, determine the perimeter of the residual chemicals above background concentrations, and evaluate the mobility of the chemical residuals in surface water in support of the risk assessment and the FS. The specific suite of analytes for samples collected from the various surface water bodies at the site were selected based upon the results of prior sampling and the understanding of historical and current site conditions as outlined throughout this Work Plan (see Sections 2.5 and 6.6.2), including the minimal surface water connections between the ponds and the swamp. As detailed in the Ecological Risk Assessment portions of this Work Plan (Section 6.6.2), the potential effects to receptors of the COPECs detected in the separate areas will be evaluated both individually by area and as groups where receptors are likely to use more than one area.

In the wetland areas the objective includes determining the concentration gradients of COPCs in the three zones suspected to be located in the wetlands as identified in the preliminary ecological risk model; the *de manifestis* zone, the intermediate zone and the *de minimis* zone. The *de manifestis* zone is the zone preliminarily defined in the field by the presence of Common Reed (*Phragmites*) and is suspected to contain LNAPL. It is anticipated that the sediments in the *de manifestis* zone will be actively remediated as the system cannot process the COPCs due to their elevated concentrations. The intermediate zone surrounds the *de manifestis* zone. In this zone the system is actively processing/sequestering the COPCs and the COPCs may have no detrimental effects on system structure. Beyond the intermediate zone is the *de minimis* zone where insignificant concentrations of COPCs exist and the wetland area is virtually unaffected. Primary sediment/surface water study objectives are the identification of the zone boundaries and the collection of data for the analysis of COPC fate and transport and for comparison to risk-based PRAOs.

Activity 5a - Gaventa and Swindell Ponds

Surface water and sediment samples will be collected from the northeast corner of Gaventa Pond and the northern portion of Swindell Pond. Prior to sampling, temperature and dissolved oxygen will be measured from the surface to the bottom of each pond in accordance with the procedures outlined in the SAP. These measurements will be collected at three locations in each pond where the water depth is at least 25 feet, based upon existing bathymetric data, and at each of the planned sampling locations. In the event that a thermocline is observed, all surface water and shallow sediment (i.e. those not specifically targeted to deeper holes in the ponds) samples will be collected from above the thermocline to provide data that is representative of exposure points for aquatic animals.

The northeast corner of Gaventa Pond is closest to the former BROS lagoon and was previously identified to have a sheen. Three surface water samples and eight sediment samples will be collected from Gaventa Pond for laboratory analysis (Figure 25). The surface water samples will be collected from the mid-depths of the pond from a boat using a weighted-bottle sampler. The surface water samples will be collected from locations designated GVT-1 through GVT-3. The pond water samples will be analyzed for chemical and geochemical parameters to support the risk assessment and to provide data on COPC fate and bioavailability. The chemical parameters, which were selected based upon historical sampling results (Section 2.5.5.2), include SVOCs and metals. The surface water samples will also be analyzed for alkalinity, TDS, TSS, TOC, hardness, DO, pH, Eh, and ferrous iron.

The sediment samples will be collected using an Eckman sampler from a boat. The eight sediment samples will be designated GVT-1 through GVT-8. The sediment sample GVT-1 will be from the deeper portion of the northeastern corner of the pond. Samples GVT-2 and GVT-6 will be collected near the northern bank and samples GVT-3, GVT-4, GVT-5, and GVT-7 will be collected along the eastern bank of the pond from locations where water depth are at least 3.5 feet. GVT-7 will be collected at a deep spot identified by CH_2M Hill (1996a) during their bathymetric study, in an area where the pond depth is expected to be more than 20 feet. GVT-8 which will be collected from along the bank in the area of the former seep. In addition, the lateral

extent of the former seep will be measured, (based upon observations of staining) during the sampling effort. This information will be used in conjunction with the soils investigation (Borings L-15A and L-15B; Figure 20) to estimate the volume of contaminants remaining in soils between the former lagoon and the northeast corner of Gaventa Pond. The sediment samples will be analyzed for chemical parameters and several geochemical parameters (Table 10). The chemical parameters include: VOCs, SVOCs, PCBs, and metals. In addition, sample GVT-1 will be analyzed for pesticides to determine whether anthropogenic pesticide contamination might influence subsequent sediment toxicity testing, if needed. The geochemical parameters to be analyzed are pH, Eh, volatile acid sulfide, grain size, TOC, and cation exchange capacity.

VOCs and metals were detected in surface water samples collected from Swindell Pond. Exceedances of the LEL for arsenic, chromium, copper, lead and zinc were identified in sample SDP-02, which was collected by CH_2M Hill (1996a). Three surface water and sediment samples will be collected for laboratory analysis (Figure 25) at the locations designated SWD-1 through SWD-3 (Figure 25). The samples will be collected in a few feet of water toward the former lagoon near proposed monitoring well cluster MW-23 (SWD-1), in the deep hole identified by CH_2M Hill during their bathymetric study (SWD-2), and near where Gaventa and Swindell Ponds have been connected (SWD-3).

The surface water samples will be collected from the mid-depths of the pond from a boat using a weighted-bottle sampler. The pond water samples will be analyzed for chemical and geochemical parameters to support the risk assessment and to provide data on COPEC environmental fate and bioavailability. The chemical parameters, which were selected to confirm the historical sampling results (Section 2.5.5.3), include SVOCs and metals. The surface water samples will also be analyzed for alkalinity, TDS, TSS, TOC, hardness, DO, pH, Eh, and ferrous iron.

The sediment samples will be collected using an Eckman sampler from a boat. The sediment samples will be analyzed for chemical parameters and several geochemical parameters (Table 10). The chemical parameters include the following metals; arsenic, chromium, copper, lead and zinc. In addition, sample SWD-2 will be analyzed for pesticides to determine whether anthropogenic

pesticide contamination might influence subsequent sediment toxicity testing, if needed. The geochemical parameters to be analyzed are pH, Eh, volatile acid sulfide, grain size, TOC, and cation exchange capacity.

Activity 5b - Little Timber Creek, Little Timber Creek Swamp and Cedar Swamp

Twenty-two surface water, 61 soil/sediment and 12 shallow ground water sampling locations are planned for Little Timber Creek and the swamp area to the east of the former BROS Lagoon between Routes I-295 and 130 and to the north of U.S. Route 130 (Figure 26). In addition, five surface water and 15 sediment sampling locations are planned for the five proposed reference areas. The sampling locations are depicted on recent aerial photographs at the request of USEPA during the initial scoping process. This figure conveys the relationship between sampling locations and wetland features (i.e. vegetation and surface water patterns). More traditional figures will be used to convey RI results.

Soil/sediment samples will be collected to characterize the concentration gradients of COPECs extending out from areas with residual LNAPL. Surface water samples will be used to determine the mobility of the residual contaminants. In addition, the sampling results will also serve as inputs to the human health and ecological risk assessment.

The sampling plan has been designed to be integrated with the water budget analysis and to:

- characterize the vertical distribution of LNAPL in the *de manifestis* zones to support an estimate of the volume of contamination;
- establish gradients of COPCs to define the intermediate zone boundaries;
- characterize the physical and chemical properties of the wetlands in support of the fate and transport analysis used for the risk assessment and FS;
- characterize the *de minimis* zone; and
- update the contaminant transport model (Figure 17).

Previous site investigations focused on the areal extent of contamination in Little Timber Creek Swamp adjacent to the former lagoon and identified the presence of site-related constituents at the downstream end of the swamp at U.S. Route 130. The sampling plan is designed to be completed in phases, using an on-site laboratory to screen sediment samples for TPH (using gas chromatography/flame ionization detection methodology) and lead. The on-site screening results will be mapped to establish gradients of contamination and develop a preliminary assessment of the boundaries between the *de manifestis*, intermediate and *de minimis* zones. Additional sampling and laboratory analysis of sediment samples, targeting a broader suite of analytes, will be completed to confirm the results of the initial screen and to provide data for the ERA. The project schedule will allow ample time for the collection and analysis of surface water and sediment samples in two phases, based upon the anticipated timing of Work Plan approval (mid-January) and the data collection requirements for the aquifer tests and the ecological sampling (i.e. field activities during April through early October).

The sampling will occur along Little Timber Creek, past Route 44 to the tidal gate and into the drainage channel to the Delaware River. Based on the retentive nature of the Little Timber Creek Swamp, the evaluation of site-related COPECs upstream of the tidal gate is focused on the residual LNAPL (*de manifestis*) area and gradients of residuals extending from them (Figure 26). In addition, several sampling locations are situated north of Cedar Swamp Road; adjacent to Route 44, and downstream of the tide gate.

Surface Water Sampling and Analysis

Twenty-two surface water samples will be collected as grab samples moving from downstream (north) to upstream (south). An additional five surface water samples will be collected at the reference areas. The specific locations of surface water samples will be defined based upon qualitative dye studies. Samples will be collected from preferential flow paths to directly characterize transport conditions. All of the surface water samples collected for chemical analysis will be analyzed for the following parameters: VOCs, SVOCs, PCBs, TPH and TAL metals. The surface water samples collected for SVOCs, PCBs, and metals will be analyzed for total and dissolved constituents as significant suspended solids may be encountered during sample

collection. A comparison of total and dissolved concentrations will provide information for assessing the mobility and bioavailability of COPECs. Approximately 50% of the surface water samples will be analyzed for the following geochemical parameters: TSS, TDS, sulfate, sulfide, chloride, nitrate, nitrite, TKN, hardness, and ferrous iron. All of the surface water samples collected will be analyzed for the following geochemical parameters: TOC, Eh, pH, DO, and alkalinity. The filtered surface water samples will also be analyzed for TOC (Table 13). In addition, ground water samples will be collected from the six wetlands monitoring wells couplets (WMW-1A through WMW-6A and WMW-1B through WMW-6B) installed in the Little Timber Creek Swamp between Routes 130 and I-295 using alternative methods, as discussed in Activity 4a.

Sediment Screening

For those sediment samples not collected from reference areas, an initial screening of sediment indicator compound concentrations using in-field analyses will be performed to assist in selecting specific sediment sample locations for full laboratory characterization. Sediment samples collected from reference areas will be analyzed at an off-site laboratory as discussed later in this section. The sediment screening locations are presented on Figure 26. TPH was selected as an indicator of organic constituents because petroleum hydrocarbons made up the majority of the mass of organic compounds released to the swamp. Other organic compounds are dissolved in the petroleum or, to a lesser degree, in the aqueous phase. Lead was identified as a potential indicator constituent for inorganic constituents since lead was identified as the sediment COPEC detected at the highest concentration in the swamp and in both the aqueous and oil phases.

The applicability of lead as an indicator was evaluated by examining possible correlations between lead concentrations and other inorganic constituents in Little Timber Creek Swamp based on a linear regression analysis (Appendix E). As discussed in Appendix E, the overall lead concentrations were, statistically, significantly correlated with barium, cadmium, chromium, copper, nickel, and zinc concentrations, but did not show statistically significant correlations with antimony, arsenic, cyanide, and silver. However, a more detailed evaluation revealed a non-linear relationship between the lead concentrations and concentrations of other inorganic constituents:

high concentrations of lead (> 1000 mg/kg) in the *de manifestis* zone showed little or no correlation with most of the analytes whereas at lower concentrations of lead (< 300 mg/kg), significant correlations existed for most of the inorganic COPECs including antimony, arsenic, barium, cadmium, chromium, copper, cyanide, nickel, silver, and zinc. Since the screening data will focus on locating sediment quality characterization samples in the intermediate and *de minimis* zones, the low concentration correlation supports the use of lead as an indicator compound for inorganic compounds. However, at lead concentrations approaching background, concentrations of silver, chromium, and cyanide could still exceed LELs. Therefore, once background lead concentrations are reached in the sediment screening, samples for more comprehensive laboratory characterization will be collected to verify inorganic concentrations. These samples will be collected in the second field phase, following an evaluation of the gradients of contaminants within the context of the probable contaminant pathways and receptor locations.

The soil/sediment samples will be collected from 76 locations using either a sediment core or a stainless steel hand auger. The sediment samples collected in and adjacent to Little Timber Creek between Routes 130 and I-295 are designated LTC-1 through LTC-39. The sediment samples collected in and adjacent to Little Timber Creek and Cedar Swamp north of U.S. Route 130 are designated LTC-40 through LTC-61.

De Manifestis Zone

From the area currently defined as the *de manifestis* zone, samples will be collected at one location north of U.S. Route 130 (LTC-50) and at six locations (LTC-5 and LTC-7 through LTC-11) from between Routes 130 and I-295 (Figure 26). The sediment samples collected from the *de manifestis* zone will be collected at six inch intervals to determine the vertical concentration gradients of the COPCs. The borings will terminate at a depth of five feet BGS or one foot below the visual or PID screening evidence of residual product, whichever is first. The samples will be analyzed for TPH and lead using the on-site laboratory. Analysis will be on a fast turnaround basis and additional samples will be analyzed if the results of the deepest sample exceed 10,000 mg/kg TPH or 500 mg/kg lead.

Intermediate and De Minimis Zones

The sediment screening locations from the areas currently defined as the intermediate and *de minimis* zones, a total of 108 samples (two depth intervals at each of the following 54 locations: LTC-1 through LTC-4, LTC-6, LTC-12 through LTC-49 and LTC-51 through LTC-61) will be collected to preliminarily evaluate the spatial distribution and concentration gradients of COPCs prior to collection of samples for confirmatory laboratory analysis. The distribution will be used to focus the confirmatory sampling locations in support of the ecological risk assessment and to define the boundaries of the intermediate zone and *de minimis* zone.

Sediment samples will be collected at locations representative of predominant habitat areas that are undisturbed by roadways and drainage culverts. Biological and chemical samples will be collected from the same locations. Further details are provided in the SAP.

Sampling Intervals

Sediment sampling will be performed for screening, confirmation, and exposure point evaluation (Figure 26). For screening purposes, sediment samples will be collected from the zero to six inch depth interval of the sediment/substrate and from the zero to six inch interval of the first inorganic layer beneath the surface to assess the mobility of COPECs. The screening samples will be analyzed in an on-site laboratory for TPH and lead. These data will be used to preliminarily determine the horizontal extent of site-related chemicals-of-concern.

The confirmatory sediment samples, which will be analyzed for a broader suite of parameters at an off-site laboratory, will be collected from the zero to six inch interval of the sediment/substrate for chemical characterization and comparison to screening values and to develop biota sediment accumulation factors (BSAFs) for burrowing receptors. In addition, samples will be collected from the zero to six inch interval of the first inorganic layer beneath the surface to assess the vertical mobility of COPECs. The confirmatory sampling locations will be established based upon the results of the screening investigations and the biota surveys described in later in this Work Plan, and will be detailed in a Technical Memorandum.

Zero to one inch interval samples will be collected at selected locations (approximately 50% of the confirmatory sampling locations) to evaluate exposure point concentrations for non-burrowing benthic receptors and receptors that utilize the surface of the swamp where it is not flooded (approximately 6 months/year); to establish the boundaries between the *de manifestis*, intermediate and *de minimis* zones; and to develop biota sediment accumulation factors (BSAFs) for non-burrowing receptors. The areas selected for sampling of the zero to one inch interval will be predominately those drier areas where the sediment is not inundated by surface water during much of the year. In defined stream channels where greater mixing and turbulence commonly occur, only the zero to six inch interval will be sampled. Any changes to the confirmatory sampling strategy will be identified in the Technical Memorandum for USEPA review and approval.

Our current understanding of the sediment food chains emphasizes the major role that epifauna plays. This understanding is supported by Kozlowski (1984), who demonstrated profound ecological and electrochemical changes and chemical transformations that occur between the aerobic and anaerobic sediment zones. The zero to one inch sampling interval was selected for the purposes of characterizing the epifauna zone consistent with regulatory guidance and current scientific literature. USEPA (1987a) guidance for sampling for organic contaminants in sediments indicates that a 2-cm depth is generally recommended to evaluate surface sediment chemistry for recently deposited sediments and that this depth holds the majority of benthic organisms and constitutes the "bioactive layer". ASTM has published several standard methods for the collection of sediment samples. The ASTM method for sediment sampling for toxicological testing indicates that that the top 1 or 2 cm is the most common depth to evaluate the depositional layer of concern (ASTM 1994). The ASTM method for evaluating the bioaccumulation of sediment-associated contaminants by benthic invertebrates recommends sampling the upper 2 to 3 cm layer because it is the most recently deposited, it is in contact with the overlying water, and represents the most biologically active zone (ASTM 1995). Thomas *et al.* (1995) found that the "feeding and reworking activities of benthic organisms are almost entirely confined to the top few centimeters of sediment" and that population densities of aquatic organisms typically decrease rapidly with depth, with up to 85% of the organisms found in the top 2 cm. USEPA (1997b)

defines exposure as "the co-occurrence of contact of the stressor with the ecological components, both in time and space" and DiBello (1975) describes the animal component of benthic systems as generally divided into infauna (animals that live within the sediments) and epifauna (animals that live on the sediment surface or just above it). Based on these considerations, different sediment sample intervals are necessary to characterize exposure points for different receptors. The proposed sampling intervals will be reevaluated after the biota survey, initial sediment sampling and reevaluation of the assessment and measurement endpoints.

Should the results of proposed sampling detect site-related contaminants above applicable sediment screening criteria or surface water standards beyond the limits of the sampling points outlined in this Work Plan, a scope of work for additional RI activities will be developed and presented to the USEPA, NOAA and NJDEP in a Technical Memorandum for approval. The initial sampling results will be evaluated statistically, using correlation coefficients, to refine the analytical suite where possible. Various COPECs will be compared against each other (e.g. lead versus total metals, TPH versus lead) to identify indicator parameters for subsequent sampling efforts. The results of the statistical analysis will be reviewed within the context of the ecological risk assessment prior to recommending changes in analytical parameters. If the analytical suite is refined, a representative percentage of the samples will be analyzed for a broader suite of analytes. The Technical Memorandum will include a summary of the results of the initial surface water and sediment sampling efforts and the recommended analytical strategy for subsequent data collection efforts.

Reference Areas

In addition to the wetland sediment and surface water samples identified above, background samples will be collected from five different reference areas (Figure 26). Six sediment samples (two depth intervals at three sampling locations) and one surface water sample will be collected from each reference area. The sediment samples collected from the reference areas are designated R-1 through R-15. The sediment/soil samples will be collected from the same depths intervals as the samples proposed for the intermediate and *de minimis* zones. The sediment/soil and surface water samples from the reference areas will serve as background concentrations of COPCs and be

used in the ecological risk assessment consistent with USEPA guidance (USEPA, 1998c). The suitability of the reference areas for use in establishing a reference condition for the site will be reevaluated based on the sampling data from the reference areas, the results of the biota surveys and inspections of wetland study areas that will be conducted as part of the Phase 2 RI, and reexamination of the assessment and measurement endpoints. This reevaluation will be summarized in a Technical Memorandum for USEPA review and approval.

Laboratory Analytes

Reference area sediment samples and confirmatory soil/sediment samples collected from the Little Timber Creek and Cedar Swamp areas will be analyzed for chemical, geochemical and waste classification parameters (Table 10). All of the soil/sediment samples will be analyzed for the following chemical and geochemical parameters: VOCs, SVOCs, PCBs, TPH, metals, DO, Eh, pH, TOC, and grain size. One sediment sample from each reference area (R-2, R-5, R-8, R-11 and R-14) will also be analyzed for pesticides. Pesticide analyses will also be performed on 10% of the confirmatory sediment samples collected from Little Timber Creek Swamp and Cedar Swamp. The locations of these samples will be detailed in the Technical Memorandum prepared following the screening phase investigation. Approximately 30% of the samples will be analyzed for volatile acid sulfide and cation exchange capacity. In addition, up to four samples will be collected for the following waste disposal parameters: TCLP VOCs, SVOCs, and metals; total PCBs; ignitability; corrosivity; reactivity; TOX and BTU content. The samples collected for waste disposal parameters will be biased to the *de manifestis* zone (i.e., former overflow area) to evaluate the remedial treatment or disposal options for the area. Further, six sediment/soil samples collected from the intermediate zone and three samples collected from the *de manifestis* zone will be analyzed for SPLP VOCs and metals to assess the leachability, mobility and bioavailability of COPECs in the sediment/soils. The location of these samples will be determined in the field based upon visual inspection and screening but the preliminary locations are LTC-7, LTC-8, LTC-14, LTC-16, LTC-25, LTC-37, LTC-44, LTC-45, LTC-50. Analysis of the *de manifestis* zone has been limited as this area will likely undergo active restoration and will not factor into an analysis of future risk.

Activity 5c - Swale Along U.S. Route 130

Surface water samples will be collected from the swale which parallels U.S. Route 130 North. The objective of the surface water sampling in the swale is to evaluate the fate and transport of COPCs; especially relative to potential background sources (e.g., highway) and the LNAPL identified in MW-L3A in the swale.

Time-weighted storm water samples will be collected during a significant rainfall event (greater than 1-inch, and preferably 2 inches in 24 hours) at two locations. The locations are (1) adjacent to Route 130 near the Cedar Swamp Road access point to Route 130 and (2) just prior to the point that the swale discharges to Little Timber Creek. The water samples will be collected directly into the appropriate sample containers, if possible. The storm water samples will be analyzed for VOCs, SVOCs, PCBs, metals and TPH (Table 6). Portions of each sample will be filtered in the field and analyzed for dissolved SVOCs, PCBs and metals to support the evaluation of COPC fate and transport.

Activity 6 - Human Health Exposure Point Concentration Evaluation

Within the baseline human health risk assessment, exposure point concentrations (EPCs) may be estimated using monitoring data alone, or a combination of monitoring data and data from environmental fate and transport models. Monitoring data are recommended for estimating EPCs for exposures pathways involving direct contact with the medium. Additionally, monitoring data provide the best estimate of current exposure concentrations. Data from fate and transport models are recommended for estimating EPCs associated with long-term exposures (USEPA, 1989) and will be useful for estimating exposures to ground water off of the BROS property. Site-specific information will be used to determine the appropriate combination of monitoring and modeling data for determining EPCs for the relevant media at the site.

Site-specific data that will be collected in support of estimating EPCs include:

- the location, depth and uses of supply wells in the area, based upon the well survey;

- areas where development will be precluded due land use restrictions, based upon the wetlands delineation; and

- the potential for land development and the likelihood that new developments will utilize public water supplies, based upon information obtained from the Logan Township Planning Office.

In addition, a determination will be made regarding whether the ingestion of fish from Swindell and Gaventa Ponds is a potential exposure pathway of concern. Such a determination will include an evaluation of the following:

- the presence and distribution of COPCs that have the potential to bioaccumulate;
- the presence of fish species that are typically consumed by humans (Activity 7a); and
- the size of the game fish population (Activity 7a).

If fish ingestion is determined to be a potential exposure pathway of concern, then further evaluations will be conducted regarding site-specific fish consumption patterns.

Activity 7 - Ecological Evaluations

The ecological field evaluations which will be completed to support the ecological risk assessment include a biological survey and biotic assessment. As specified in the BROS Consent Decree, these biological surveys could not be completed prior to approval of the Phase 2 RI/FS Work Plan. Therefore, the existing ecological evaluation scope of work was developed based upon limited site visits and existing information detailing potential species at the site. The primary objectives of this portion of the field investigation are to identify the ecological receptors at the site and to determine if ecological receptors are or will be affected by site-related COPCs. The evaluation will focus on a comparison of biological characteristics between the study areas (e.g., intermediate and *de minimis* zones) and the reference areas. The field investigation which will be performed as part of the biological survey and biotic assessment are presented below.

Subsequent phases of the Ecological Evaluation will include the sampling and analysis of animal tissue, the evaluation of macroinvertebrate community characteristics, and the performance of sediment toxicity tests. The specific animal tissue types, analytical procedures, target analytes, and test methods will be determined based upon the results of the initial phase of sediment and surface water sampling and the completion of the biological surveys described below. Samples will be collected from appropriate trophic levels to assess exposures through the food chain. Sediment toxicity testing and macroinvertebrate community analyses along sediment contamination gradients of the swamp will provide an effects measure for assessment endpoints related to direct contact exposures. Sediment sample locations for toxicity testing and collocated sediment chemical characterization samples will be selected to represent the contamination gradient across the site, based on the results of the sediment field screening. The scope of work, proposed sample locations, sampling and analytical methodologies, and DQOs for tissue studies and sediment toxicity testing will be included in the Technical Memorandum describing the initial phase of sediment and surface water investigations.

Activity 7a - Biological Survey

The biological survey component of the biological evaluation will include the following:

- general biological receptor survey;
- fish population evaluation;
- habitat (vegetation cover) evaluation; and
- wetland delineation.

These activities are described in Task VIB (Section 6.6.2) and their procedures are identified in the SAP.

Activity 7b - Biotic Assessment

The biotic assessment of the ecological evaluation will be phased and will include the following;

- comparison of the species composition of several communities with reference sites;

- determination of aquatic macroinvertibrate densities and abundance; and
- collection and chemical characterization of tissue from measurement endpoints, selected after the biological survey.

These activities are described in Task VIB-Ecological Risk Evaluation and the respective procedures are identified in the SAP.

6.3.2 Task IIIB - Data Analysis

Activity 1 - Data Validation

To ensure that the data is usable for site characterization and risk assessment purposes, data will be validated using either the *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA, 1994a), *USEPA Region II CLP Organics Data Review and Preliminary Review* (SOP No. HW-6, Revision 8) (USEPA, 1992b), *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (USEPA, 1994b) and/or the *Evaluation of Metals Data for the Contract Laboratory Program* (SOP No. HW-2, Revision #11) (USEPA, 1991c) or the same guidelines modified for non-CLP analyses. The level of complete transcription checks (raw data to reporting for calculation checks) shall nominally be 10 percent, but this percentage may be increased or decreased depending on the nature and significance of the individual results. A more detailed discussion of data validation procedures is provided in the QAPP.

Activity 2 - Data Reduction

Data reduction involves the generation, interpretation and calculation of results from the field and laboratory analyses performed as part of the data gathering effort. In order to make the defensible decisions, it is necessary to verify that the reported values are correct, both in the way they have been generated (instrument calibration, etc.) and the way they are calculated and reported. Due to the different quantities of documentation and the different quality levels of data generated in the field and the laboratory, somewhat different levels of effort are required for data reduction and usability verification for these different data sources. The data usability evaluations outlined in Exhibit 3-3 of RAGS Part D (USEPA, 1998f) will be applied for the human health risk

assessment. Data reduction for the human health risk assessment is discussed in more detail in Section 6.6.1.

All of the newly installed monitoring wells and all soil borings installed in the former Lagoon and Process Areas will be surveyed by a New Jersey Licensed land surveyor. The sampling points will be located according to the New Jersey State Plane coordinates and surveyed for elevation in reference to the National Geodetic Vertical Datum (NGVD). The soil, sediment, surface water, and ecological sampling locations will be located either by surveying or the use of Global Positioning System (GPS) technology depending upon the accessibility of the location and the presence or absence of a vegetated canopy, which may limit the use of GPS technology. The sampling point data obtained using surveying and GPS technology will be input into a geographic information system (GIS). All of the laboratory data will also be obtained via electronic file transfer and linked to the GIS which will allow for the GIS posting of analytical data on maps and GIS creation of thematic maps (i.e., maps with symbols of different sizes, shapes and colors to indicate different concentration ranges). The database system supporting the BROS Phase 2 RI/FS will employ a Microsoft Access® platform, which can be provided in electronic format for integration with the NJDEP GIS system.

Field Data Reduction

Raw data from field measurements and sample collection activities will be appropriately recorded in the field logbook. All measurement data recorded in field logbooks or field forms will be reviewed by the Project Manager or his designee for completeness and clarity. Any discrepancies noted will be resolved by the Project Manager. Any field information entered into data systems will be subject to the QA/QC procedures provided in the QAPP.

Laboratory Data Reduction

The off-site laboratory will perform analytical data reduction and validation under the direction of the Laboratory QA Officer. The Laboratory QA Officer is responsible for assessing data quality and advising of any data which were rated "preliminary" or "unacceptable" or other notations which would caution the data user of possible unreliability. Prior to data reduction and reporting,

the data will be validated as described in Section 6.3.2 - Activity 1 and the data usability will be assessed using Exhibit 3-3 of RAGS Part D (USEPA, 1998f) and *Guidance for Data Usability in Risk Assessment* (USEPA, 1990c). Data reduction reporting procedures will be those specified in the CLP SOW for inorganic and organic analyses.

Laboratories will prepare and retain full analytical and QC documentation for CLP analyses as required by the Contact Laboratory Program. For non-CLP analyses, the laboratories will prepare and retain full analytical and QC documentation similar to that required by the Contract Laboratory program. The laboratory will report the data in chronological order along with all pertinent QC data.

Activity 3 - Data Evaluation

After data is reduced as described above, the results will be graphically integrated to facilitate a 3-dimensional interpretation of distributions of COPCs and COPC gradients in various portions of the site. Hydrogeologic, geochemical, and geotechnical data will be evaluated for the AOCs and for the site as a whole. Hydrogeologic and chemical data from the CLTL site, including information developed during the pumping tests, remedial design and remedial action, will be considered where appropriate. The results of these interpretations will be used to support the risk assessment and the evaluation of remedial alternatives based upon the objectives and data and technical evaluation needs summarized in Section 5.1.

Soil and ground water quality data collected as part of the methods comparability studies will evaluated to establish the variability between the traditional and new sampling methodologies. For soils, the evaluation of collocated samples using ice and methanol preservation will be conducted through a comparison of VOC results for collocated sample. Concentrations of total VOCs and those of individual compounds will be compared to assess whether differing chemical properties (e.g. Henry's constant, solubility, functional groups) and soil characteristics influence the relative difference between preservation methods. The results of laboratory matrix spike duplicate samples will be used to estimate the degree that sample heterogeneity and matrix interference yield variations in sample results. The results of the soils methods comparability

analysis will be used to reevaluate the existing soil data and, where practical, use the historical data along with the new data in the estimate of the volumes of soils that exceed the PRGs.

For ground water, the evaluation of VOC concentrations in wells sampled using traditional and low-flow purging methods will include comparisons for individual sampling events and for multiple events over time. The results of this analysis will serve as a basis for comparing current ground water quality data collected using the low-flow sampling methodology with historical data collected using conventional sampling methods. This comparison will be used to characterize temporal changes in ground water quality. Concentrations of total VOCs and those of individual compounds will be compared to assess whether differing chemical properties (e.g. Henry's constant, solubility, functional groups) and aquifer characteristics influence the relative difference between sampling methods. Further, evaluations of the same wells over multiple events will be used to develop a mean and standard deviation for the differences observed. This statistical assessment will be used to estimate to what degree temporal changes in VOC concentrations are related to sampling methodology.

Data evaluation activities in support of DNAPL investigations will be conducted based upon the USEPA OSWER guidance *Evaluation of the Likelihood of DNAPL Presence at NPL Sites* (USEPA, 1993f and the USEPA Office of Research and Development Research Report *DNAPL Site Evaluation* (USEPA 1993g). The DNAPL investigation includes field tests for the presence and characteristics of DNAPL (Section 6.3.1, Activity 3) and the analysis of laboratory data for conditions that suggest the presence of DNAPL as described below. Based upon all of these studies, a weight of evidence approach will be applied to determine whether DNAPL exists at the BROS site.

New laboratory data collected during the Phase 2 RI/FS will be evaluated for conditions that indicate potential DNAPL (USEPA 1993f). Historical data will not be evaluated as, with the exception of the Phase 3 RI data, it does not reflect current conditions or the influence of the lagoon work. The Phase 3 soils were predominantly analyzed for BTEX compounds only,

providing insufficient data for the assessment of chlorinated VOC components. The DNAPL data evaluation tasks will include assessment based upon:

- the vertical gradients of DNAPL-forming constituents in ground water;
- the variability in ground water quality over time;
- an analysis of the predicted solubilities of DNAPL-forming constituents in ground water based upon mole fractions; and
- an evaluation of soil/water partitioning relationships.

Based upon the mole fraction of DNAPL-forming components in DNAPL mixtures detected at the site, if any, ground water analytical results will be compared to determine whether the concentrations of DNAPL-related constituents exceed 1% of their pure phase solubility or their effective solubility. Laboratory results from soil samples that contained greater than 10,000 mg/kg total VOCs, or from soil samples that are suspected of containing DNAPL based upon dye testing and an assessment of the relative abundance of DNAPL-forming components to petroleum hydrocarbons, will be evaluated for DNAPL based upon a partitioning calculation as presented in Feenstra, et. al. (1991).

Activity 4 - Environmental Fate and Transport Analysis and Modeling

Classification Exception Area

The CEA process has been initiated based upon USEPA concurrence. Initially, the CEA will be established for the Upper PRM and the Upper Middle PRM over the area underlying the BROS property and extending to I-295. If warranted after the initial comprehensive ground water sampling round, a modified CEA proposal will be presented to the NJDEP for the area where the concentrations of site-related contaminants currently exceed, or will exceed, the New Jersey GWQC, N.J.A.C. 7:9-6. The CEA will be updated during the Phase 2 RI/FS as new information pertaining to the dimensions, longevity, or constituents of concern for the CEA are developed. The CEA includes (NJDEP, 1995):

- a written and mapped description of the area in which constituent standards are not or will not be met;
- an identification of the contaminants for which the CEA has been established; and
- an estimate of the longevity of the CEA.

As specified in N.J.A.C. 7:9-6.6(a), the CEA application will identify the proposed CEA boundaries mapped on a 7.5 minute USGS quadrangle map and described using the longitude and latitude of the area. The description will also include the lot and block numbers of the affected or potentially affected properties. The identification of each aquifer that is subject to the CEA, and the extent of the CEA for each aquifer, will be presented. The CEA will include the identification, for each aquifer, of the site-specific contaminants that exceed the NJ GWQC. A map of the CEA will be prepared for inclusion in the NJDEP's GIS database. The longevity of the CEA will be estimated for each COPC in each aquifer using published pollutant degradation rates, site-specific geochemical factors (e.g. electron couples, TOC, DO, Eh) and an assessment of temporal and spatial trends in ground water quality.

Inter-Media Transfer Evaluation

The magnitude of COPC transfer among site media will be evaluated in order to estimate transport mechanics between soil and ground water. The evaluation will be based on data collected during Task III activities and will address transport from unsaturated soil to ground water, saturated soil/sediments to ground water and saturated soil/sediments to surface water.

Transport of COPCs, from soil/sediments to water is dependent upon the geochemical properties of the water, the concentrations of COPCs in soil/sediments, the geochemical properties of the soil/sediments and the geotechnical and hydrologic properties of the system. The detailed identification and characterization of COPCs performed as part of Task III will be used to quantify the nature of COPCs, relative to potential transport. The nature of the soil relative to transport of COPCs will be characterized by the geotechnical and geochemical data collected as part of Task III. Specifically, geotechnical parameters such as porosity and hydraulic conductivity

will define the potential storage and transmissive, respectively, capabilities of the soil. The TOC, volatile acid sulfide and cation exchange capacity values, will be used to estimate partitioning and attenuation. These values will be used to evaluate the leachability of the COPC for soil and will be compared to SPLP analyses to evaluate expected transport.

The hydrologic and hydrogeologic evaluations will allow an estimate of flux of infiltrating water percolating through unsaturated soil and ground water flows through saturated soil. The flux of water will be used in conjunction with the soil evaluation and water quality data to estimate the likely COPC flux from media to media. This evaluation will also include an estimate of the number of pore volumes and associated restoration timeframes for flushing or pumping technologies.

Ground Water and Surface Water Modeling

The following section outlines the scope, methods and model codes associated with the planned modeling activities for the Phase 2 RI/FS. The level of detail provided is consistent with the administrative requirements of the Consent Decree (Appendix E, Task IIIB).

Surface water and ground water modeling will include the water budget analysis (Pierce, 1993) which integrates data from the various surface water and ground water components of the conceptual model on a seasonal basis. The numerical modeling and water budget analysis will be completed in an iterative fashion. Data from the water budget data collection activities (e.g. water elevation, flow rates, evapotranspiration rates) will be used in the numerical modeling. Modeling results (e.g. discharge/recharge rates, discharge boundaries) will be used in the water budget analysis. Detailed analysis of specific components of the conceptual model will be completed through numerical ground water flow, fate and transport modeling and surface-water modeling performed during the remedial investigation. The modeling will be conducted to support the risk assessment and evaluation of remedial alternatives.

The objectives of the ground water modeling are as follows:

- to simulate the water-table elevation and potentiometric surfaces under both static (non-pumping) and simulated pumping conditions;

- to simulate the fate and transport of the COPCs of concern in the Upper and Upper Middle PRM aquifers;

- to estimate the concentrations of COPCs at potential downgradient receptors;

- to estimate the contaminant mass flux from ground water to surface water at discharge points based upon the results of collocated samples and the water budget;

- to simulate the transport and fate of contaminants in the wetlands and surface water;

- to evaluate the water-budget mass balance; and

- to evaluate the potential for natural attenuation to occur at the site.

In order to achieve these objectives, the following components of ground water flow, fate and transport modeling and surface-water modeling will be performed:

- construction of a ground water model grid and surface-water model mesh based on published and field data;

- model calibration to approximate field conditions, including sensitivity analyses to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of model parameters;

- verification of the calibrated model by simulating at least one transient event for which there are hydrogeologic data;

- quantitative assessment of constituent concentrations at receptor locations over time, which can be used for risk characterization;

- evaluation of constituent migration pathways through ground water and surface water;
- evaluation of all potential source areas that may be contributing contaminants to the aquifer, ponds and wetlands;
- evaluation of the effectiveness of remedial alternatives such as natural attenuation, plume containment, and ground water pump-and-treat remediation; and
- quantification of volumetric and mass fluxes at ground water discharge points.

Surface water modeling will be performed using empirical methods in order to evaluate:

- the flux of COPCs leaving the Little Timber Creek Swamp at U.S. Route 130; and
- the general sources of COPCs within Little Timber Creek Swamp.

Hydrographs, consisting of water level evaluations versus time plots, will be prepared for each monitoring point. Where staff gauges are nested with wetlands monitoring wells, the hydrographs will be superimposed upon each other. The hydrographs will be used to compare ground water elevation data to surface water elevation data. Evaluation of the hydrographs will then be conducted to determine if, and where, surface water discharges to ground water or ground water discharges to surface water and if there are seasonal variations between these relationships. Net flow data will be evaluated by comparing flow readings from the surface water gauging stations (FM-1 through FM-4) and data from staff gauges SG-9 (located at the interconnection between Swindell Pond and Little Timber Creek Swamp) and SG-13 (located in Little Timber Creek upstream of Route I-295). The volumetric flow into and out of the Little Timber Creek Swamp will be calculated based upon a comparison of the sum of the upstream points (FM-1, FM-3 and FM-4) with the flow at the discharge point (FM-2). Staff gauge readings form SG-9 and SG-13 will be compared to the surface water elevations at other, nearby, points to qualitatively evaluate the potential for other sources of surface water inflow to the study area. Hydrographs will also be compared to assess the storage dynamics of the Little Timber Creek Swamp under differing seasonal and hydrologic conditions.

Tidal and barometric pressure influences on surface water and ground water elevations will be evaluated through a comparison of meteorological and tidal data (from direct measurements and regional sources such as NOAA and the DRBC) with water levels measured using pressure transducers connected to data loggers. Although maximum tidal fluctuations of five feet have been measured in Little Timber Creek near its confluence with the Delaware River, a tide gate eliminates most recognizable tidal fluctuations upstream of U.S. Route 130 (CH_2M Hill, 1996a). Moreover, tidal influences were not observed in the Upper PRM during studies completed by CH_2M Hill (1996a).

The modeling of sources will be based upon a comparison of the results of collocated ground water and surface water samples and the hydrologic data from the water budget analysis. Surface water sampling will be conducted along preferential flow paths, as identified through dye studies, to establish a realistic estimate of COPC transport. Secondary objectives of the surface water modeling efforts are to provide data to the ERA and to refine the identification of the boundaries of the *de manifestis* zone and the intermediate zone.

Geochemical modeling will be employed, if necessary. The use of synthetic precipitation leaching procedure analysis of sediment samples from the intermediate and *de manifestis* zones will be used for empirical evaluation of COPC leachability, mobility and bioavailability.

Model Code Selection

The criteria used for ground water and surface-water model code selection was based upon the guidelines provided in the *Assessment Framework for Ground Water Model Applications* (USEPA, 1994c). The guidelines highlight reliability and usability as key criteria for model code selection. The models chosen have all been proven reliable through years of use in the public and private domain and are based on widely accepted hydrologic principles and governing equations. The usability of each model has been enhanced in recent years with the advent of graphical user interface pre- and post-processing programs. The models chosen have all undergone extensive testing and peer review, are industry standards and components of each model are in the public domain.

The modeling code will be used without modification. However, additional or proprietary modeling code may be required during performance of the modeling task to complete the scope of work. Should this situation arise, a Technical Memorandum will be written as an addendum to the Work Plan to address the use of the additional code, and full supporting documentation of the code will be provided.

Ground Water Model Codes

Based on a review of the geological and hydrological data, a 3-dimensional numerical analysis will be required to model the ground water flow system and address modeling objectives. The ground water flow model that will be used is the USGS Modular Ground Water Flow Model (known as MODFLOW) by McDonald and Harbaugh (1988). $MODFLOW_{win32}$, which is an updated version of MODFLOW that has been modified for use with current 32-bit operating systems, will be used to perform the simulations. The fate and transport modeling will be performed using $MT3D^{96}$ (Papadopulos & Associates, Inc., 1996). $MT3D^{96}$ is designed to be used with a block-centered finite-difference flow model such as MODFLOW. Both MODFLOW and MT3D were used to perform ground water flow, fate and transport modeling at the adjacent Chemical Leaman site.

Geochemical Modeling (Contingency)

If necessary, geochemical modeling would be conducted with MINTEQA2, an equilibrium geochemical model which is developed to determine speciation of chemical components in dilute aqueous environments. The fate and transport behavior of a particular chemical component of species is strongly dependent upon the geochemical environment through which it migrates. Results from MINTEQA2 speciation model would, therefore, be used in conjunction with fate and transport modeling to predict migration behavior of various aqueous components along a specified flow pathway(s). Input for this fate and transport model will include analytical data for the chemical components of interest and geochemical data which define the aqueous system, such as pH, Eh, dissolved oxygen, and alkalinity. Given the heterogeneity of the sediments in Little Timber Creek Swamp, geochemical modeling will likely require a substantial data collection effort and may not produce data that is more useable than that from column leaching studies. As such, column leaching studies (Section 6.5) will be used to gather empirical data for the assessment of mobility, leachability and bioavailability. MINTEQA2 will be used as a contingency.

Ground Water Model Construction

An iterative model-construction procedure will be utilized beginning with data collection and evaluation, and development of a conceptual model. The conceptual model is a representation of the fundamental components of the hydrogeologic system and is used to formulate cause-and-effect relationships. The grid extent, number of layers, characterization of sources and boundary conditions will be determined based upon the conceptual model, the water budget analysis, and the distribution of COPCs . All data (published and field collected) characterizing the hydrogeologic and chemical aspects of the flow system will be compiled and evaluated to determine their relevance to the modeling processes. These data will include information from the aquifer studies and, if available, ground water extraction data at the CLTL site. Fundamental data pertinent to model construction are discussed below.

For the ground water model, a preprocessing program, Ground Water Vistas (Environmental Simulations, Inc., 1996), will be used to create the finite-difference grid, locate and designate the boundary conditions, and define the elevation of the bottoms of the model layers. Ground Water Vistas will also be used to input parameters such as well discharge rate, hydraulic conductivity, transmissivity, storativity, leakage, evapotranspiration, stream-bed characteristics, and recharge from precipitation, and to create the input files for $MODFLOW_{win32}$. The input of elevation data for use in defining model layers into the MODFLOW model will be facilitated through the use of SURFER™ (Golden Software, Inc., 1996) via Ground Water Vistas.

MODFLOW will also be coupled with a particle-tracking program commonly referred to as MODPATH (Pollock, 1989). MODPATH provides particle-tracking options to illustrate the directions of ground water flow and delineate capture zones from pumping wells for evaluating pump and treat remedial alternatives.

Data Requirements

The hydrogeologic data to be used to construct the ground water flow model include the following:

- well data from throughout the flow system, including well construction details, soil boring and well logs and ground water levels to physically characterize flow-system geometry, composition, and extent (boundaries); and head-and-flow conditions (obtained from published sources and field investigations);

- aquifer-test data to quantify hydraulic coefficients (transmissivity, storativity, hydraulic conductivity, leakage), to determine boundary conditions (i.e., no-flow, constant head, flux), and to evaluate induced infiltration from surface-water bodies;

- precipitation and recharge data (from published sources and field data) to estimate recharge distribution throughout the study area;

- system stresses, such as past, current, and future pumpage and artificial recharge to ascertain their impact on the flow system; and

- surface-water/ground water relationships, as well as supplemental data defining stream-bed lithology, size, depth, and water levels of surface-water bodies.

The hydrogeologic and chemical data needed to construct the fate and transport model include the following:

- water-quality data, to characterize water-quality conditions and trends;

- aquifer medium characteristics such as:

  - effective porosity, which is required to calculate ground water velocities (which in turn affect travel time of constituents in the aquifer);

  - dispersivity, which is a measure of the spread of contaminants as they move through the flow system;

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- the distribution coefficient, which relates to the movement of the solute relative to the movement of the ground water; and

- solute decay via biotransformations as it moves through the flow system, (from published sources and field data);

- timing of the release of compounds into the ground water (if possible); and

- source characterization, such as type of constituent, continuing source, decaying source, and/or intermittent source.

The data required for construction of the ground water flow, fate and transport model will be obtained from the initial data collection and analysis performed during the RI.

Existing Models

The conceptual model used for construction of the model grid will incorporate regional data from existing ground water flow models including the following:

- *Ground Water Flow Conditions in the PRM Aquifer, Camden Area (NJGS, 1995);*

- *Digital Simulation and Projection of Head Changes in the Potomac-Raritan-Magothy Aquifer System, Coastal Plain, New Jersey (USGS, 1980); and*

- *The Technical Memorandum for Ground Water Flow Modeling, Chemical Leaman Tank Lines Inc., Bridgeport, New Jersey (Ground Water Associates, Inc., 1997).*

To the extent practicable, the existing models will be used as a guide toward defining model grid extents, boundary conditions, and initial and historic flow conditions.

Model Calibration

Calibration of a model refers to demonstration that the model is capable of producing field-measured heads, flows and concentrations. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses (i.e., pumping rates) that produce simulated hydraulic heads (water levels) and fluxes that match field-measured values within a pre-established range of error. This pre-established range of error is usually the residual mean or absolute residual mean of the difference between the field-measured values and the model-produced values.

Model calibration will be performed using a combination of trial-and-error and parameter estimation software (i.e., automated calibration). In trial-and-error calibration, parameter values are initially assigned to each node or element in the model grid. During calibration, parameter values based on field and published data are adjusted in sequential model runs to match simulated model results to the field-measured values. For automated calibration, Roux Associates, Inc. will use parameter estimation software, which automatically adjusts parameters to obtain model calibration.

The results of the model calibration will be evaluated both quantitatively in tables and qualitatively on maps. The tables will present the comparison between field-measured and model-simulated values (i.e., hydraulic heads, fluxes and solute concentrations) and quantify the difference as residual and absolute residual means. The maps will provide a means of qualitatively evaluating the calibrated model representation of field-measured values using water-level contours and plume isoconcentration contours.

Sensitivity Analysis

The purpose of a sensitivity analysis is to quantify the uncertainty in the model results caused by uncertainty in the estimates of input parameters, stresses and boundary conditions. During a sensitivity analysis, values for parameters and boundary conditions are systematically changed within the ranges identified during the review of existing data. Sensitivity analysis is typically performed by changing one parameter at a time. The magnitude of the resulting change in the

model output relative to the calibrated solution is a measure of sensitivity of the model to the uncertainty in a particular parameter.

For the ground water flow model, sensitivity analyses will be performed for hydraulic conductivity, storativity, recharge and boundary conditions. For the solute fate and transport model, sensitivity analyses will be performed for dispersivity, degradation half-life and retardation factor.

Model Verification

The objective of model verification is to simulate at least one other transient event for which there are hydrogeologic data. This will include simulation of the proposed aquifer tests to evaluate how well the model simulated field-measured stresses on the flow system.

Model Simulations and Presentation of Results

Model simulations will be performed to evaluate remedial alternatives, including natural attenuation, and to predict the fate and transport of the compounds of concern at the site. Pumping simulations will be performed using several modeled pumping well configurations to evaluate pumping and treatment as a remedial alternative and to investigate the potential for negative impact of ground water pumping on the wetlands. The pumping simulations will be performed under a range of recharge scenarios to evaluate the effect of drought and high recharge events on contaminant capture by pumping wells.

Simulations to evaluate natural attenuation will be performed both with and without simulated pumping wells. The goal of these simulations is to determine whether natural attenuation can be a viable stand-alone remedial alternative, or will require additional engineered source control measures (i.e., hot spot pumping).

The results of the model simulations will be presented using:

- tables of model-predicted heads and concentrations at monitoring points throughout the flow system;

- graphs of predicted ground water quality versus time at monitoring points and potential receptor locations;

- maps depicting simulated water levels and flowpaths delineated by particle tracking; and

- maps depicting simulated contaminant distributions with time under various remedial scenarios.

Ground Water Model Input into the Surface-Water Model

User-specified mass fluxes are used as input into RMA4, which is the contaminant transport component of the surface-water model. To determine the mass fluxes at ground water discharge points into surface water, the following steps will be used:

- the USGS program ZONEBUDGET (Harbaugh, 1990) will be used to calculate the ground water volumetric flux into surface water at specified discharge points;

- the contaminant concentrations will be measured at the discharge points, or estimated based upon available ground water monitoring data; and

- fluxes will be calculated by multiplying the ground water volumetric fluxes by measured or estimated contaminant concentrations.

ZONEBUDGET is a program that calculates subregional water budgets using results from MODFLOW. Once the mass fluxes are calculated, the results will be used as source functions for input into specified nodes or node ranges in the surface-water model mesh.

6.3.3 Task IIIC - Data Management Procedures

Activity 1 - Documentation of Field Analysis

All field activities will be documented in bound notebooks or on pregenerated, activities-specific field forms. The goal of field documentation to provide a clear and complete record which can be referenced and/or retrieved at a later date. Specific direction for the management of field

logbooks, documentation field activities, sample documentation, and documentation of field custody procedures is provided in the SAP.

Activity 2 - Sample Management and Tracking

All samples will remain under a chain of custody from the time of collection to analysis. A field chain custody will be initiated by the sampler at the time of sampling. Sample custody will be relinquished by the sampler a the time of pickup by the laboratory or submittal to an express mail service. After the samples are delivered to the laboratory, they will be logged in, stored, and tracked as described in the QAPP. The Field Team Leader will be responsible for coordinating with the laboratory manager to ensure that deliverable schedule are met and all analyses are performed. A more detailed discussion of sample management and tracking is provided in the QAPP. Field reports, sample shipment records, analytical results and QA/QC reports will be maintained and evaluated to ensure only validated data is reported.

6.3.4 Task IIID - Site Characterization Deliverables

Activity 1 - Site Characterization Summary Report

A Site Characterization Summary Report will be submitted to the USEPA after completion of the field sampling and analysis in accordance with the schedule presented in Section 8.0. The Site Characterization Report will summarize the investigative activities that have taken place during the Phase 2 RI and present data generated which identifies the locations and characteristics of surface and subsurface features and COPCs at the site which includes the affected medium, location, types, physical state and concentrations of COPCs. The Site Characterization Summary Report will also identify the location, dimensions, physical condition and varying concentrations of each COPC throughout each source and the extent of COPC movement through each of the effective media, as appropriate. To the degree appropriate, specific AOCs or "hot spots" will be defined for purposes of data analysis and presentation. The Site Characterization Summary Report will provide the preliminary reference to develop the baseline risk assessment and to evaluate the development and screening of remedial alternatives and the refinement and identification of ARARs.

6.4 Task IV - Identification of Candidate Technologies

Candidate technologies, including innovative technologies, have been identified and evaluated as part of the RI/FS scoping activities (Section 4.0, Table 7). In accordance with USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a) the candidate remedial technologies are general categories of technologies such as chemical treatment, thermal destruction or capping. Several potential process options may be included within the technology type. For example, *in-situ* treatment of ground water includes aerobic bioremediation, anaerobic bioremediation, biosparging, natural attenuation, reaction walls, and *in-situ* oxidation.

Based upon the initial scoping process, Section 4.5 outlines a number of candidate technologies for treatability studies, along with the primary objectives of the treatability study. This listing is intended to fulfill the administrative requirement for identification of treatability studies in the Consent Decree (Appendix E, Task IV). As outlined in Task V and the approved Phase 2 RI/FS schedule, treatability study scoping and work plan preparation will be completed based upon the initial site investigation data. The Treatability Study Work Plan will be submitted within five months of Work Plan approval assuming the initial site investigation data are collected on schedule.

Within the FS process, the evaluation of candidate technologies is principally a function of implementability and effectiveness based upon the RI data and site characteristics. This approach was applied to the Work Plan scoping effort as well, although the screening employed a greater latitude based upon the current data needs and the objective of developing a comprehensive, yet decision-relevant, data collection program. The screening also considered the variability between differing areas of the site (e.g. the Little Timber Creek Swamp as compared to the Gaventa Pond, incinerator wastes as opposed to soils in the former Process Area) and technologies were retained even if they are likely to be limited to specific areas of concern. The results of the technology screening were carried through to the screening of process options and the development of remedial alternatives (Section 4.4).

The current listing of candidate technologies will be reevaluated and refined during the site characterization process in support of the development of remedial alternatives (Task VIII) and the alternatives analysis (Task IX) based upon the data collected. New and emerging technologies will be added to the list, if applicable, and the evaluation will be refined based upon new site data and recent published literature on the performance of candidate technologies.

6.5 Task V - Treatability Studies

As summarized in Section 4.5, treatability studies and/or pilot tests may be conducted in order to more fully evaluate the effectiveness, implementability and costs of certain remedial alternatives. These studies may be conducted to assess new or innovative technologies, to provide input to the remedial alternatives development and screening process, and to provide data to support the conceptual design and costing of remedial alternatives in support of the FS. The results of treatability studies will be incorporated into the FS process, as appropriate. Initial treatability testing activities (such as research and study design) are being performed concurrently with Work Plan scoping and site characterization activities.

The SPLP analyses described in Section 6.3 will be used to provide a basis for the selection of samples for subsequent column leaching tests as part of the treatability study activities. More specifically, the chemical testing, SPLP and permeability results will be used to select a range of stratigraphic units, contaminant types and contaminant concentrations for column leaching tests. The column leaching studies will be conducted using ASTM Method D 4874 - *Test Method for Leaching Solid Waste in a Column Apparatus*. Depending upon the data needs at the time of the column leaching studies, the studies may be completed using ground water from background wells, from an alternative nearby, uncontaminated, source of water from the same aquifer, or from a synthetic source.

The Consent Decree (USDC, 1997a) specified that a Technical Memorandum be submitted to identify candidate technologies for a treatability studies program during project planning. Section 4.5 of this document has been prepared to meet that requirement.

If practical candidate technologies have not been sufficiently demonstrated as to there effectiveness or cost for site-specific conditions, or if they cannot be fully developed and evaluated during the detailed analysis portion of the FS on the basis of available information, treatability testing will be conducted. Where treatability testing is required provide the data necessary to complete the detailed analysis, a Treatability Study Work Plan will be prepared which identifies the scoping of pilot testing and treatability studies. The SAP, QAPP and HASP from the Phase 2 RI/FS will be amended, if necessary, to address the activities to be performed during the treatability tests. The Treatability Study Work Plan and associated documents will be submitted during the early stages of the Phase 2 RI as identified in the schedule (Section 8.0). The Treatability Study Work Plan will be provided within five months of approval of the RI/FS Work Plan

Following completion of treatability testing, the data will be analyzed, interpreted, and presented in a Technical Memorandum to the USEPA. Depending on the scope and sequence of activities, this report may be a part of the Phase 2 RI/FS report or a separate deliverable. The report will evaluate each technology's effectiveness, implementability, cost and actual results as compared with predicted results. The report will include an evaluation of full scale application of the technology, including a sensitivity analysis identifying the key parameters affecting full-scale operation.

The Treatability Report will present the results of the treatability studies and will evaluate each technology's effectiveness, implementability, cost and evaluate full scale application. The Treatability Report will be submitted in accordance with the schedule (Section 8.0).

6.6 Task VI - Baseline Risk Assessment

The risk assessment is divided into two separate but related components: human health risk assessment and ecological risk assessment. Both are completed concurrently with other RI activities and will be used in the Feasibility Study along with other considerations to determine where appropriate risk management actions should be completed.

6.6.1 Task VIA - Human Health Risk Assessment

The overall goal of the RI/FS process is to provide a framework for developing the information necessary for remedial decision-making at sites (USEPA, 1989a; USEPA, 1991d). The goal of the human health risk assessment is to provide the information necessary to support an informed risk management decision on the protection of human health. In addition, it is important to recognize that information should be developed only to determine what actions are necessary to reduce risks, and not to fully characterize site risks or eliminate all uncertainty from the analysis. More specifically, the human health risk assessment evaluates both current and future potential risks to human health posed by chemicals remaining at the site. Since significant remediation has already been completed at the site, the risk assessment addresses potential risks associated with any residual chemicals remaining at the site.

The three basic parts of the RI/FS human health evaluation that are described in the following section are:

- Part A - Baseline Risk Assessment (USEPA, 1989a);
- Part B - Refinement of risk-based PRGs (USEPA, 1991d); and
- Part C - Evaluation of remedial alternatives risk (USEPA, 1991e).

The USEPA has recently (USEPA, 1998h) released a new guidance document entitled *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part D), Standardized Planning, Reporting and Review of Superfund Risk Assessments* (RAGS Part D). This publication explains the role of risk assessment in the CERCLA process by:

- reiterating guidance provided in RAGS Parts A, B and C should be used concurrently with Part D;

- requiring all of the data presentation be standardized to allow it to be entered into the CERCLIS 3 database; and

- discussing the role of risk assessment in remedial alternatives evaluation and in the implementation of a ROD or an amended ROD.

Activity 1a - Baseline Human Health Risk Assessment

Risk Assessment Methodologies

Regulatory agency guidance for conducting site-specific human health risk assessments was initially presented in the publication *Superfund Public Health Evaluation Manual* (USEPA, 1986)(SPHEM). This document was subsequently modified and published as *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A* (USEPA, 1989a) (RAGS Part A). The USEPA has issued supplemental risk assessment guidance since 1989. The purpose of these additional guidance documents (i.e., Memoranda and Directives from the Office of Solid Waste and Emergency Response [OSWER]) is to provide risk assessment guidance that, when used in conjunction with RAGS Part A, reflects the recent developments in risk assessment methods and approaches. For example, recent guidance provides information on the calculation of the concentration term used in the risk assessment, the identification of exposure scenarios, the use of a risk-based concentration screening process and the consideration of temporal changes in site conditions and contaminant concentrations. The following is a list of additional risk assessment guidance documents, in addition to those listed in the Consent Decree, likely to be applicable to the risk assessment at the BROS site:

- USEPA, 1991f. Memorandum from Timothy Fields and Bruce Diamond. Subject: *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive 9285.6-03

- USEPA, 1992c. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Office of Solid Waste and Emergency Response. OSWER Intermittent Bulletin 9285.7-081

- USEPA, 1992d. Memorandum from F. Henry Habitat, Deputy Administrator to Assistant and Regional Administrators. Subject: *Guidance on Risk Characterization for Risk Managers and Risk Assessors.* February 26, 1992.

- USEPA, 1992e. *Dermal Exposure Assessment: Principles and Applications.* Office of Health and Environmental Assessment. USEPA/600/8-91/011B.

- USEPA, 1993b. *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening.* USEPA Region III Technical Guidance Manual Risk Assessment.

- USEPA, 1993c. *Superfund's Standards Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure*. Preliminary Review Draft (5/5/93).

- USEPA, 1994d. Memorandum from Elliott P. Laws, Assistant Administrator to Regional Administrators. Subject: *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities.* OSWER Directive 9355.4-12. July 14, 1994.

- USEPA, 1995a. Memorandum from Carol M. Browner to Assistant, Associate and Regional Administrators, General Counsel and Inspector General. Subject: *EPA Risk Characterization Program.*

- USEPA, 1995d. Memorandum from Elliott P. Laws, Assistant Administrator to Regional Directors. Subject: *Land Use in the CERCLA Remedy Selection Process.* OSWER Directive 9355.7-04. May 25, 1995

- USEPA, 1995f. Memorandum from Elliott P. Laws, Assistant Administrator to Regional Administrators. Subject: *OSWER Directive 9610.17: Use of Risk-Based Decision-Making in UST Corrective Action Programs.* March 1, 1995

- USEPA, 1996h. Soil Screening Guidance: Technical Background Document. OSWER 9355.4-17A. EPA/540/R-95/128. May 1996; Soil Screening Guidance: Fact Sheet. OSWER 9355.4-14FSA. June 1996 (USEPA, 1996i); and Soil Screening Guidance: User's Guide. OSWER 9355.4-23. EPA/540/R-96/018. April 1996.

- USEPA, 1997e. *Exposure Factors Handbook. Volume I of III: General Factors.* Office of Research and Development. EPA/600/P-95/002Fa.

- USEPA, 1997h. Guiding Principles for Monte Carlo Analysis. Risk Assessment Forum. EPA-630-R-97-001.

- Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997. Framework for Environmental Health Risk Management. Final Report.

- USEPA, 1998e. Institutional Controls: A Reference Manual. Draft prepared by the USEPA Workgroup on Institutional Controls. March 1998.

- USEPA, 1998f. Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual. Part D: Standardized Planning, Reporting, and Review of Superfund Risk Assessments. Interim. Publication 9285.701D. January 1998.

- USEPA, 1998g. Supplemental Guidance to RAGS: The Use of Probabilistic Analysis in Risk Assessment. Part E: Working Draft.

- USEPA, 1997g. Risk-Based Concentration Table. USEPA Region III, Superfund Technical Support Section.

The Baseline Risk Assessment will be conducted in multiple steps. It will include as an interim deliverable the Exposure Pathway Analysis Report which will be presented in the form of a Technical Memorandum. The five phases of the risk assessment as described in RAGS Part A (USEPA, 1989a) are data collection; data evaluation; exposure assessment; toxicity assessment; and risk characterization. These phases are discussed in more detail later in this section.

After the completion of the data evaluation phase, the Exposure Pathway Analysis Report will be prepared to present the USEPA with:

- a list of chemicals detected in each medium, including the total number of samples and the frequency of detection on an AOC-by-AOC basis;
- information on the treatment of data (e.g. non-detects, statistical analysis) and the calculation of exposure point concentrations:
- identification and rationale for selection of individual AOCs;
- a list of chemicals selected as COPCs and the methods used to select the chemicals;
- the toxicity values and the source from which they were derived for each COPC identified; and
- an initial exposure pathway analysis.

The purpose of this report, which will be consistent with the exposure assessment process outlined in RAGS Part A, will be to develop consensus with USEPA Region II on key parameters that will be used in the exposure assessment. Additionally, the Exposure Pathway Analysis Report will summarize the issues discussed and resolved at technical meetings held during the conduct of the remedial investigation.

The exposure pathway analysis will be divided into the following exposure assessment steps:

Step 1: Characterization of the exposure setting.

Step 2: Identification of exposure pathways, with emphasis on analysis of the four elements of an exposure pathway:

- Source and mechanism of release.
- Retention or transport medium (or media).
- Points of potential human contact.
- An exposure route at the contact point.

The Step 2 analysis will be presented in the form of a set of matrices of potential exposure route (See Exhibit 6-7 of RAGS Part A for an example).

Step 3: Quantification of Exposure: General Considerations

Based on the data and the result of Steps 1 and 2, the Technical Memorandum (Exposure Pathway Analysis Report) would present the planned or proposed process of quantifying the magnitude, frequency, and duration of exposure for populations and exposure pathways selected for quantitative evaluation, consistent with applicable guidance and policies available at that time.

The following sections describe the scope of work for the five phases of the risk assessment.

Data Collection

A quantitative human health risk assessment must be based on reliable chemical release and exposure data collected from the site (USEPA, 1989a). At the BROS site, a large amount of data has been generated over the past twenty years. However, to accurately estimate the exposure point concentrations and risks, the exposure points concentrations must be specifically measured in a manner that can be related directly to potential current or future receptors. Such an approach has been incorporated into the sampling design and methods presented throughout the Work Plan, as well as the QAPP and SAP. The risk assessment approach developed for the BROS site emphasizes the following elements:

- a detailed conceptual model of the site;
- background conditions in soils, surface water, and ground water;
- site-specific characterization of probable exposure frequency and duration by determining current and future receptor activities in various portions of the site;
- sampling at the locations of actual and potential exposure points in a manner that will yield representative concentrations;
- estimating exposure point concentrations using the most recent and representative data available for each area. Recognizing that the BROS site Phase 2 RI/FS is a

retrospective study, meaning the release of contaminants occurred primarily in the past and concentrations along exposure pathways will continue to decline in the future, fate and transport modeling will be used to estimate future chemical concentrations.

- evaluating risks posed by the entire site, in addition to areas of concern or hot spots which are distinguished by differing chemical types, concentrations, sources of contamination, spatial or temporal variability, sampling methods employed and/or other relevant factors;

- realistic data quality objectives based on site-specific conditions; and

- recognition that there can be significant interrelationships between the human health risk assessment and the ecological risk assessment, especially when the results of both baseline risk evaluations are taken into consideration in the feasibility study.

The data gathering efforts of the Phase 2 RI are intended to collect data that are relevant to the risk assessment to the degree practical. For example, surface soil samples will be collected from both the upper two inches of the soil column to better represent the concentrations associated with most exposures (USEPA, 1989a) and the 2 to 12 inch interval to assess risk in the event of shallow excavation or tilling of the soil. In other instances, due to the sometimes conflicting data objectives of risk assessment and engineering assessment, data will be collected that is more representative of the maximum concentrations. An example is the use of 10 foot well screens at the bottom of the Upper PRM, when regional conditions and traditional practice would suggest a longer screen interval near the top of the aquifer is more representative of types of wells that would be installed by ground water users. In these instances, the risk assessor will use empirical data and/or professional judgment in determining how to apply the data.

Not all previously generated data will be relevant to the risk assessment. For example, source removal (i.e., removal of the lagoon) has been conducted at the BROS site. Thus, soil data developed during the RI and associated with the lagoon area are not relevant to the risk assessment since those soils have been removed from the site. Similarly, ground-water data

generated prior to conclusion of the lagoon work are not representative of site conditions for purposes of the risk assessment as they were collected between five and eight years ago and are not representative of current or future risk scenarios. Only the three most recent rounds of ground water data generated since the conclusion of the lagoon work will be used in the estimation of current risk during the risk assessment. Concentration trends and fate and transport modeling will be used to estimate future potential exposure concentrations and risk to downgradient receptors. Input data for these evaluations will reflect the results of the ground water sampling comparability studies. Based on the location of previously established wells and the proposed additional wells, data from approximately 80 wells will be used in estimating potential exposure concentrations and associated risks.

Data Evaluation

The data for the BROS site is from several different sampling periods (over the decades), including pre-Phase 1 RI/FS activities, Phase 1 RI/FS, preliminary Phase 2 RI data, and ongoing site characterization activities; and is based on several different analytical methods. Consequently, the data will be evaluated from different time periods to determine the changes which have occurred. Older data will be kept separate from the most recent data, which will be used in the quantitative risk assessment. The older data will be used in an analysis of the changes of concentrations over time. The data evaluation process planned for the BROS site will be primarily consistent with guidance provided in RAGS Part A (USEPA, 1989a). The data and associated qualifiers will be statistically analyzed using an EXCEL® macro. All available analytical data for environmental media (soils, surface water, ground water and sediment) at the site that are applicable to the risk assessment will be included in the data evaluation process. However, where appropriate, guidance from RAGS Part D (USEPA, 1998f) and the *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E) will be integrated into the data evaluation process.

As part of the data evaluation, the risk assessment will evaluate each media at the site and identify discrete AOCs or hot spots where this approach is supported by the RI data and exposure scenarios. The state of New Jersey has defined AOCs to mean "any existing or former location where hazardous substances, hazardous wastes, or pollutants are or were known or suspected to

have been discharged, generated, manufactured, refined, transported, stored, handled, treated, disposed, or where hazardous substances, hazardous wastes, or pollutants have or may have migrated..." (N.J.A.C. 7:26E). AOCs are similar to operable units (OUs) described in RAGS Part A (USEPA, 1989a), except they are not managed on an administratively separate track. An OU is defined in the National Contingency Plan (NCP) as "a discrete action that comprises and incremental step toward comprehensively addressing site problems." (USEPA, 1989a). Use of the AOC approach allows site conditions to be addressed in a focused manner, especially when the site-related constituents are distributed over a large area in different media. Furthermore, AOCs are beneficial for grouping regions of a site that share common potential uses, chemical characteristics and/or physical settings. For example, the Gaventa Pond area, the BROS property and the Little Timber Creek wetlands area are three possible AOCs. Each of these three areas have unique potential exposure scenarios. While restricted human activity is established for the BROS property, it is expected that there will be very little human activity in the wetlands area due to the presence of dense vegetation and water cover. Possible exposure scenarios for Gaventa Pond include trespassing with subsequent surface water exposure (e.g., swimming, fishing, boating) whereas fishing, boating and swimming are unlikely exposures in the wetlands. For the Baseline Risk Assessment all analytical data associated with a given AOC will be considered as a separate unit as well as taking the entire site conditions into account.

Following the complete data evaluation process, the number of potentially site-related chemicals may still be quite large. Based on the diversity of site-related chemicals, especially petroleum constituents, it will not be practical to quantitatively evaluate each potentially site-related chemical, COPCs will be identified based on frequency of detection, essential nutrient considerations and a risk-based screening methodology.

Frequency of detection screening will be applied to addressed compounds that may be detected infrequently and do not have available toxicity factors, such as non-aromatic hydrocarbon compounds. Compounds without available toxicity factors will be address qualitatively in the risk assessment. The frequency of detection of chemicals found at the BROS site will be evaluated for the site as a whole and for each AOC in the event that certain compounds are identified only in

discrete locations. RAGS Part A recommends a process by which chemicals may be eliminated from the risk assessment if they are:

- detected infrequently in one or two environmental media;
- not detected at high concentrations; and
- there is no technical basis to conclude the chemical may be present in the media.

The example of a 5 percent frequency of detection limit given in RAGS Part A will be used as point of departure for not including chemicals in the risk assessment. However, selection of a detection frequency limit for the risk assessment will be considered in conjunction with the total number of samples available for each medium.

The risk-based screening methodology will use a combination of toxicity factors (reference doses and/or cancer potency factors) with protective conservative default exposure scenarios for industrial or residential uses to estimate concentrations in environmental media (soil, air, water, fish) corresponding to fixed levels of risk. For carcinogens, the risk based concentrations that correspond to a lifetime cancer risk of 1E-6 represent protective environmental concentrations that the USEPA would typically not address further in terms of risk to human health (USEPA, 1993b). For noncarcinogens, a systemic hazard quotient of 1.0 was generally used for screening purposes. Recent USEPA guidance (USEPA, 1998i) suggests that where multiple chemicals are present in a medium, a hazard quotient of 0.1 should be used to ensure that chemicals with additive effects are not prematurely eliminated from the risk assessment. In some cases the use of a hazard quotient of 0.1 can result in the inclusion of a potentially carcinogenic chemical based upon its noncarcinogenic properties. Any such inclusions will be evaluated for relevance. Furthermore, chemicals will not be retained if they are not detected, provided the numeric DQOs are achieved. As using a more sensitive end point for screening purposes could result in the inclusion of a significantly greater number of chemicals being carried through the risk assessment, particular attention will be paid to ensuring that the appropriate screening value (e.g. residential versus industrial) is selected and that inclusion can be justified based upon the frequency of detection. Risk-based screening will not be used to eliminate chemicals from the dermal exposure

pathway. All assumptions used to develop the risk-based screening concentrations will be presented in the Exposure Pathway Analysis Report.

For purposes of the constituent selection process, the maximum concentration of each chemical detected in a given medium at a discrete AOC or hot spot will be compared to the appropriate (either residential or industrial) risk-based concentration for that medium (i.e., obtained from USEPA, 1998i). The identification and rationale for selection of individual AOCs will be provided to USEPA as part of the Exposure Pathway Analysis Report. Typically, the maximum concentration is used in the screening process to identify chemicals that do not require further evaluation based on their presence in media at concentrations below any level of concern (USEPA, 1993b). This does not imply that the maximum concentrations of chemicals detected in media at the site will be used in the site-specific risk assessment since this procedure has been superseded by USEPA guidance that emphasizes the most realistic approach is appropriate. The future potential uses of the site will be reviewed to determine whether industrial or residential risk-based concentrations are more appropriate. If the maximum concentration of a chemical within an AOC exceeds the risk-based concentration, then the chemical will be retained for quantitative analysis. Otherwise, the chemical will not be addressed quantitatively in the risk assessment. After this screening process is completed, some additional screening may be undertaken if the number of constituents is large but a significant number do not substantially contribute to the overall risks (USEPA, 1989a).

There may be some chemicals present at the site for which no screening values are currently available from the USEPA. If possible, surrogate risk-based concentrations will be calculated for these compounds using the methodology developed by Region III and appropriately identified toxicity factors. Otherwise, these chemicals will automatically be retained for qualitative analysis.

Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to constituents of potential concern present at the site. Exposure is defined as the contact of a

human with a chemical or physical agent, while the magnitude of exposure is determined by measuring or estimating the amount of an agent available at the exchange boundaries during a specified time. Adjustment for the amount of an agent that is absorbed across the exchange barrier is made in the risk characterization step. Estimates of current exposures will be based on the most recent data and future exposures estimated based on trends in the data over time and modeling. The exposure assessment consists of the following three components:

- Characterization of the exposure setting.
- Identification of exposure pathways.
- Quantification of exposures.

Characterization of the Exposure Setting

Characterizing the physical setting involves a review of both the physical environment (Section 2.0) and the potentially exposed populations. As previously stated, the site will be evaluated in its entirety, by media, and by major AOCs based upon a logical interpretation of the RI data and exposure scenarios. Each portion of the site will be reviewed to determine which exposure scenarios (e.g., industrial use, trespassing, etc.) are relevant for the receptors (persons) who may utilize the AOC. (For example, based upon site inspections to date, there is no direct evidence of potential human exposure to the COPC residuals in Little Timber Creek wetlands. The dense vegetation and presence of marshy areas in the wetlands will significantly limit the likelihood of human exposure via trespassing.) For each AOC, future planned land use will be considered for purposes of identifying future potential receptors. Where certain receptors use multiple AOCs or the whole site, the risk results will be combined by weighting the relative amount of time spent in each AOC.

For ground water, the current potential receptors will be based on the survey of ground water use which will be completed as part of the Phase 2 RI/FS. Future ground water receptors will be determined consistent with the planned future use and relevant regulatory considerations.

Land Use Considerations

The reasonably anticipated future use of the land at a site is an important consideration in determining the appropriate exposure pathways (USEPA, 1995d). Determining the future land use assumptions for a site is necessary to focus the risk assessment and feasibility study on the assessment of realistic potential risks and the development of practicable remedial alternatives leading to site activities which are consistent with the reasonably anticipated future land use of the site (USEPA, 1995d). For purposes of evaluating future potential risks, the risk assessment will consider the planned future use of the BROS property and surrounding parcels.

As part of the settlement between the operators of the BROS facility and the settling defendants, three perpetual deed restrictions have been established and properly recorded for the BROS property, which is the location of the Pepper Building, the former lagoon and the former Process Areas (Figure 2). These deed restrictions are as follows:

- Future use of the property excludes residential use and limits other uses to non-retail commercial and/or industrial use. These uses are consistent with the use of the property when the releases began.

- All subsurface activities (e.g., digging) are prohibited without prior written approval of the USEPA and NJDEP.

- The installation and/or use of any ground water wells at the site is prohibited without prior written approval of the USEPA and the NJDEP.

In addition, a proposal to NJDEP for a Classification Exception Area (CEA) for ground water will be prepared and will likely be in effect prior to the completion of the Phase 2 RI. These institutional controls will be taken into account within the context of the OSWER Land Use Directive (USEPA, 1995d) and additional guidance on institutional controls that are effect at the time of the risk assessment.

Identification of Exposure Pathways

Exposure pathways describe the mechanism by which receptors may come into contact with chemicals present in environmental media. A complete exposure pathway has four components:

- Source and method of release.
- Transport medium.
- Point of human contact.
- Exposure route (i.e., ingestion, dermal absorption, etc.) (USEPA, 1989a).

The risk assessment will quantify only complete exposure pathways (i.e., those pathways for which all four of the above components are present). In addition to the general site conceptual model (Figures 4 and 17), a conceptual exposure model will be prepared for the site and each major AOC or hot spot to provide a visual representation of the relevant exposure pathways for that individual AOC. An example of a conceptual model that will be used to assess potential concerns at each AOC is provided (Figure 30). In conjunction with the conceptual model, a summary table will be provided to present the rationale for inclusion or exclusion of each potential pathway for a particular AOC (Table 14 is an example).

Quantification of Exposures

For all potentially complete pathways identified in the conceptual model, potential exposures to receptors will be estimated. Quantification of exposures involves estimating exposure concentrations and quantifying pathway-specific intakes.

The approach of using either the arithmetic mean or the 95 percent UCL on the arithmetic mean of the chemical concentrations in a medium to estimate potential exposures and risk does not take into account either the spatial distribution of that chemical or the likely attenuation over time. Segregating the site into AOCs and modeling the fate and transport of chemicals of potential concern are key components for integrating possible exposure concentrations over any likely exposure period.

For purposes of quantifying potential exposures, the USEPA guidance recommends presenting a range of risks using multiple risk descriptors such as central tendency (which is used for exposure pathways exhibiting unacceptable risk) and high end of individual risk (USEPA, 1992c, 1995a) as a means of establishing realistic exposures. The high end risk descriptor is defined as "a plausible estimate of the individual risk for those persons at the upper end of the risk distribution" (USEPA, 1992c). The high end risk descriptor is not a worst case scenario (USEPA, 1992c). So-called "worst case" scenarios represent a combination of events that result in a hypothetical risk that has a negligible probability of occurring due to redundant conservative assumptions which each have a very low probability of occurrence. (USEPA, 1992c, 1995a). Although it is theoretically possible that such an exposure could occur, the probability of an individual receiving this type of exposure is so small that such an exposure will not occur in a particular, real population (USEPA, 1992c, 1995a). USEPA discarded the use of "worst case" exposure scenarios for CERCLA and other sites over ten years ago (USEPA, 1986c). The primary objective when developing an estimate of high-end exposure of dose is to arrive at an estimate that will fall within the actual distribution, rather than above it.

Monte Carlo simulation (also known as probabilistic or stochastic analysis) is a useful tool to apply in the risk assessment process to gain a better understanding of the influence of uncertainty identified in the deterministic risk characterization. The USEPA Science Policy Council (1997) outlined the conditions for using Monte Carlo analysis to develop more realistic risk assessments. RAGS Part E provides guidance on the appropriate use of Monte Carlo to better characterize the range of risk at a site taking into consideration the multiple uncertainties associated with a deterministic assessment of risk. A recently released draft document, RAGS Part E (USEPA, 1998g), provides more detailed guidance on the considerations to be weighed in the conduct of a probabilistic risk assessment. Current, relevant USEPA guidance for probabilistic risk assessment will be used for the baseline risk assessment.

The exposure assessment may utilize Monte Carlo analysis to describe the range of likely exposures. A Monte Carlo analysis is a statistical technique whereby a quantity is repeatedly calculated using randomly selected "what if" values for each input into the calculation. The inputs

into a Monte Carlo analysis are described not as single values but as random variables with probability distributions. The results of a Monte Carlo analysis provide a range of risk estimates that describe the probability as well as the magnitude of possible outcomes.

Much of the site-related data was collected from samples biased to visual indicators of contamination and to areas close to sources. Data distributions used in the Monte Carlo analysis will be selected to reflect the bias in the sample collection. Since the USEPA protocol for performing a Monte Carlo analysis is expected to be refined in the near future, the most recent Monte Carlo guidelines will be reviewed at the time the exposure assessment is performed. A discussion of the protocol used in the Monte Carlo analysis will be provided in the Exposure Pathway Analysis Report, consistent with the policy for Monte Carlo analysis at the time. It is anticipated that distributions will be estimated for parameters such as receptor body weight and frequency and duration of exposure in the Monte Carlo analysis. Consistent with current USEPA guidance (USEPA, 1998c), toxicity values (reference doses and cancer potency factors) will not be considered as distributions. The Monte Carlo analysis will be conducted with Crystal Ball® software, unless EPA is notified otherwise.

Exposure scenarios developed for the site and each major AOC will be limited to those exposures consistent with the land use or deed restrictions, as appropriate (i.e., residential or industrial/commercial). Consistent with USEPA guidance, exposure scenarios developed will be realistic and scientifically balanced (USEPA 1992d, 1995a). Unrealistic exposure scenarios that are inconsistent with the probable future land use at the site will be eliminated from consideration, consistent with EPA policy and guidance (USEPA, 1995a,b). Based upon the information received from the Pennsgrove Water Company, public water supplies are now in place throughout the area of the site including the BROS property and extending to Swedesboro-Paulsboro Road. Thus, should any new development occur in this area, the potable water supply would be available from the municipality. Institutional controls further limit the likelihood of exposure. The presence of wetlands severely restricts (both from a feasibility and a permitting perspective) the potential for construction on the BROS property and on areas to the east. The ground water use

restrictions imposed by the deed restriction further reduce potential exposures to ground water on the BROS property.

During the Baseline Risk Assessment the BROS property deed restrictions will be considered for purposes of determining future potential/land uses. Other deed and/or use restrictions such as Classification Exception Areas, may be applied on the site in the future for varying amounts of time. These restrictions will also be considered within the context of future potential activities at the site, consistent with policies and guidance available at that time.

Site-specific demographic data will be reviewed for purposes of determining receptor characteristics, such as population mobility. Since the intent of the exposure assessment is to describe plausible receptor exposures, use of data from monitoring wells with screened intervals of just 10 feet may provide an unrealistic estimate of exposure to chemicals in ground water. Persons installing a potable well downgradient of the site are unlikely to install wells with long screen intervals (i.e., than 20 feet). As such, the biases associated with the 10 foot well screen will be considered when estimating possible exposures to chemicals in ground water downgradient of the site.

Potential chemical intakes will be calculated using equations presented in RAGS (USEPA, 1989a). Conservative but realistic, health-protective assumptions that take into account site-specific information will be used to estimate the exposure variables utilized in the intake equations. Fate and transport modeling will also be used to describe the movement and natural attenuation of chemicals present in the environmental media over time. Recommended values for exposure variables presented in RAGS (USEPA, 1989a) and other USEPA guidance documents will be reviewed for applicability to the site. All of the anticipated exposure variables used in the risk assessment, and the rationale for their selection, will be presented in the Exposure Pathway Analysis Report.

Toxicity Assessment

The purpose of the toxicity assessment is to examine the evidence for individual chemicals to cause adverse effects in exposed populations. The toxicity assessment also provides an estimate of the extent of exposure to chemicals to increase the likelihood that adverse effects will occur.

An individual toxicological profile will be provided for each of the chemicals that are quantitatively evaluated in the risk assessment. The toxicological profile will include a brief outline of potential adverse effects, both noncarcinogenic and carcinogenic, that may be associated with exposure to that chemical. If available, the toxicological profile will also contain data regarding the chemical's mechanism of action for its toxic effects. Chemical specific data, such as reference doses and cancer potency factors, will be obtained, as available, from the *Integrated Risk Information System* (IRIS) (USEPA, 1998d), the *Health Effects Assessment Summary Table* (HEAST) (USEPA, 1995e) or the National Center for Exposure Assessment (NCEA). Since IRIS is the USEPA data base containing only agency-verified RfDs and slope factors (CPFs), IRIS is the preferred source of toxicity information. Therefore, only if information is not available in IRIS for the chemical being evaluated will other sources (i.e., HEAST) be consulted. The National Center for Exposure Assessment will be contacted if information for a given chemical is not available from either IRIS or HEAST. If no slope factor or reference dose is forthcoming from IRIS, HEAST or NCEA, an attempt will be made to develop a reference dose or slope factor for a chemical or a grouping of chemicals by class based on the toxicity of structurally related compounds, if available. The basis for this approach, which will only be conducted if sufficient data are available to develop a scientifically defensible methodology, will be submitted to the USEPA for discussion. Chemicals that cannot be addressed in this manner due to a lack of appropriate data will be discussed in the uncertainty section.

Risk Characterization

The risk characterization integrates the toxicity and exposure assessments into qualitative and quantitative expressions of risk. Noncarcinogenic effects are characterized by comparisons of projected intakes of the noncarcinogenic compounds to toxicity values (references doses or

benchmark doses). Carcinogenic effects are characterized by expressions of the probability that an individual will develop cancer over a lifetime of exposure based on projected chemical intakes and dose-response information.

For each exposure scenario, hazard quotients (HQs) will be estimated for all chemicals that are either considered to be noncarcinogens or have noncarcinogenic mechanisms of action (i.e., those compounds with a reference dose.) The hazard quotient is the ratio of the exposure level (intake) occurring during the period of exposure to the reference dose. A hazard quotient will be calculated for each exposure route. HQs from each exposure route will then be summed to present a single HQ for each noncarcinogenic compound.

For noncarcinogens, the mechanism of action of the chemical and the specific target organ of that chemical will be reviewed prior to summing the HQs to produce a hazard index (HI). Recent guidance from the USEPA and the SAB directs that noncancer risks (i.e., HQs) should be added only for those chemicals with the same toxic endpoint or mechanism of action (USEPA, 1993e). As such, the HQs will be segregated by target organ in the event that the HI exceeds 1.0. The uncertainties associated with summing and segregating the HQs will be addressed. Uncertainties that will be considered include variations between animal species selected to generate dose-response data and the extrapolation of the dose-response data from animal studies to man.

For each exposure scenario, incremental lifetime cancer risks (ILCRs) will be estimated for all chemicals that are considered to be carcinogens or to have a carcinogenic mechanism of action (i.e., those compounds with a cancer potency factor). For carcinogens, risks are defined as the estimated increased risk that occurs over an assumed average lifetime (70 years) as the result of exposure to a carcinogenic chemical. For each chemical in the given exposure scenario, an ILCR will be calculated for each exposure route. ILCRs from all exposure routes will then be summed to present a single ILCR for each chemical.

The additivity of carcinogenic and noncarcinogenic effects for multiple chemicals from single or multiple exposure pathways will be considered in the risk assessment based on the most recent

guidance from the USEPA and the Science Advisory Board (SAB) at the time the risk assessment is conducted. Based on the considerable uncertainties associated with chemical interactions, the USEPA promotes summing of carcinogenic risks regardless of whether the exposures to the potential carcinogens are occurring simultaneously (USEPA, 1989a). However, the USEPA recognizes that there are several limitations to this approach, including summing cancer risks from substances with different weights of evidence for human carcinogenicity (USEPA, 1989a). Roux Associates, Inc. will sum the carcinogenic risks for chemicals with similar mechanisms of toxicity, exposure routes, and target organs consistent with USEPA policy and guidance at that time. For example, available data indicate that cadmium is only carcinogenic following the inhalation route of exposure, while benzene is considered to be carcinogenic by both inhalation and ingestion but has a specific target site, bone marrow.

Baseline Risk Assessment Report Preparation

The results of the quantitative risk analysis will be reviewed in order to determine which chemicals or groups of chemicals are the major contributors to the potential risks at the site and various portions of the site. To assist in the review of this information by USEPA and the public, the RAGS, Part D specified table formats will be used for presentation, although the complexity of site conditions dictates that other spreadsheets also be used to complete the quantitative risk analysis. Since the site is comprised of different AOCs with unique exposure scenarios, a review of the potential hazards and risks associated with each of the individual AOCs provides a more complete understanding of any potential risks associated with the site. The assessment of risk for various AOCs is necessary because of the complexity of site conditions; specifically the spatial variability of COPC types and COPC concentrations and the multiple receptor/exposure scenarios which relate to the diversity of site features (e.g. swamps, private land).

Individual tables (similar to Tables 9.1 and 10.1 in RAGS, Part D) will be prepared which summarize the HIs and ILCRs for all chemicals associated with all exposure scenarios in each given AOC and in each media. The summary and discussion will also include a qualitative discussion of the uncertainties in the risk assessment process. All uncertainties will be discussed in terms of either potentially overestimating risk, potentially underestimating risk or having an unknown contribution.

In addition to the quantitative risk assessment, a qualitative assessment of the exposure pathways resulting in significant potential quantitative risks will be completed to identify points in the pathway which could potentially be managed to substantially reduce the quantitative risks. This activity will assist the risk manager by adding perspective which is decision-relevant.

Deliverables

As stated previously, the Exposure Pathway Analysis Report will be submitted following the data evaluation phase in order to finalize key elements to be used in the exposure assessment section of the risk assessment. The baseline risk assessment report will be an attachment to the RI/FS report and will contain all of the components listed in the suggested report outline provided in RAGS (USEPA, 1989a). A summary of the risk assessment will be presented in the text of the Phase 2 RI/FS.

Activity 1b - Preliminary Remediation Goals

As outlined in Section 3.2, a preliminary list of COPCs has been developed based on available site-specific information (CH_2M Hill, 1996a). Initial PRGs have been defined based on a review of ARARs and TBCs. Site-specific risk-based PRGs will be developed twice during the RI/FS, once following collection of the first round of data and once concurrent with the Baseline Risk Assessment. PRGs will be established based upon ARARs, TBCs, published toxicological information and site-specific exposure assumptions. Where applicable, the PRGs will be used to update the list of COPCs and, subsequently, modify the analytical suite for additional sampling rounds. A step-wise approach will be adopted for the Phase 2 RI/FS.

At the outset of this project, data available for establishing initial PRGs are generally between four and seven years old. In the interim period there has been source removal activity and organic chemical degradation can reasonably be predicted to have occurred. Thus, following the first round of data collection at the BROS property, the PRGs will be reevaluated to provide a basis for scoping subsequent data collection rounds and to incorporate additional risk-based PRGs. A Technical Memorandum will be prepared to describe modifications to PRGs, including the addition of chemicals (such as breakdown products) previously not found and the elimination of chemicals that no longer appear to be present. As subsequent rounds of data are collected, PRG

evaluation will continue in an iterative fashion to ensure that DQOs are maintained and that the RI activities collect data that is relevant to the risk assessment and FS processes.

During the Baseline Risk Assessment, the PRGs will be modified. As stated in RAGS (USEPA, 1989, 1991), the approach for refining the PRGs involves the following steps:

- Identifying levels based on risk assessment where chemical-specific ARARs are not available or situations where multiple chemicals or multiple exposure pathways make ARARs not protective.

- Identifying non-substance specific goals for exposure pathways, if necessary

- Determining a refined preliminary remediation goal that is protective of human health and the environment for all chemicals and exposure pathway combinations addressed in the risk assessment.

For example, the risk assessment will use the most recent and appropriate site-specific data, largely excluding the data generated prior to the conclusion of the lagoon work. A discussion of the PRG refinement process will be incorporated into the Baseline Risk Assessment Report. The results of the Baseline Risk Assessment, including the refined PRGs, are used to develop the final remediation goals for the site. These final remedial goals are used to review possible remedial alternatives for the site.

Activity 1c - Remedial Alternatives Risk Evaluation

During the performance of the FS, risk evaluation is used to ensure that the remedial action objectives and the preliminary remediation goals are consistent with the risk reduction requirements necessary for an alternative to meet CERCLA's protectiveness criteria, and that the risks associated with various remedial alternatives can be compared. A risk evaluation will be conducted for each remedial alternative selected (Task VIII). The NCP specifies that one of the criteria for considering the effectiveness of a remedial alternative is to evaluate the short-term and long-term human health risks. The process of evaluating remedial alternatives will begin in the

development and screening phase of the FS. As stated in RAGS Part B and Part D (USEPA 1991d and 1998f) the primary goal for the risk evaluation is to provide decision-makers with the specific information needed to choose among the remedial alternatives. The site-specific questions that must be answered in order to select a final remedy will be reviewed in order to determine the appropriate level of effort for the risk evaluations.

During the risk evaluation phase, each remedial alternative will be evaluated according to the nine evaluation criteria established in the NCP and then compared to each other. Both long-term and short-term potential human health risks and environmental impacts associated with a given remedial alternative will be considered. Long-term human health risks associated with a remedial alternative are those risks that remain following the completion of the remedy (i.e., residual risks). An example of evaluating residual (long-term) risk is comparing estimates of the final chemical concentration that a remedial alternative is expected to achieve with the remedial goal for that chemical in the particular medium. Short-term human health risks associated with a remedial alternative are those risks that occur during the implementation of the remedial alternative. An example of short term potential human health risks are potential risks associated with emissions from incinerators or similar equipment installed at a site for remedial purposes. Information produced in the risk assessment such as data regarding the exposure pathways and exposure concentrations will be used to analyze both short and long term risks associated with remedial alternatives for the BROS property.

The results of the risk evaluation of remedial alternatives will be presented in a Technical Memorandum which will be included in the FS Report.

6.6.2 Task VIB - Ecological Risk Assessment

The scope of the Ecological Risk Assessment (ERA), is presented below, in accordance with EPA guidance for CERCLA sites (USEPA, 1997b). The ERA scope has been prepared based on site information generated by USEPA's contractor, several site visits, the ecological assessment generated for the nearby Chemical Leaman site (Barnett, 1993), and other EPA guidance for the

performance of ecological risk assessments (USEPA, 1998c) and reference site selection procedures (USEPA, 1996).

As applied to Superfund site assessment, ecological risk assessment is a qualitative and/or quantitative evaluation of the actual or potential effects of site contaminant exposures on plants and animals other than humans and domesticated species. A risk does not exist unless: 1) a stressor has the ability to cause adverse effects, and 2) it contacts an ecological component long enough and at a sufficient intensity to be absorbed in sufficient doses to elicit the identified adverse effect. The functions of the ERA are to:

- determine whether actual or potential ecological risk exists at a site;
- identify which contaminants present at a site pose an ecological risk; and
- generate data for risk management decisions.

The ecological risk evaluation process under CERCLA is comprised of eight steps and several scientific/management decision points (SMDPs) (USEPA, 1997b). SMDPs are significant communication points which function to focus the ERA as more information becomes available and evaluate the need for reductions in uncertainties. Each SMDP will be discussed at one of the monthly meetings with the USEPA, scheduled for the duration of the Phase 2 RI/FS. The eight steps are:

Step 1 Screening Level Problem Formulation

Step 2 Screening Level Exposure Estimate and Risk Calculation

SMDP

Step 3 Baseline Risk Assessment Problem Formulation

SMDP

Step 4 Study Design and Data Quality Objectives Process

SMDP

Step 5 Verification of Field Sampling Plan

SMDP

Step 6 Site Investigation and Data Analysis

SMDP

Step 7 Risk Characterization

Step 8 Risk Management

SMDP

The first four steps were completed based on existing site information. A conceptual site model was developed for the design of the baseline ecological risk assessment. This ERA section of the Work Plan presents the results of the first four tasks of the ERA: 1) Screening Level Problem Formulation and Ecological Effects Evaluation, 2) Screening Level Risk Calculation, 3) Baseline Risk Assessment Problem Formulation, and 4) Study Design and Data Quality Objectives. However, the screening level risk calculation efforts are limited due to data gaps regarding receptors and chemical concentrations in the environmental media.

Review of the ERA section of the Work Plan and Field Sampling and Analysis Plan is a SMDP (Step 4) for USEPA to approve the approach and design of the baseline risk assessment, conducted through the completion of the remaining steps. Steps 5 and 6 involve the implementation of field data collection activities and the interpretation of the data for characterizing risk under Step 7. In Step 8, the results of the ERA are utilized as a basis for calculating risk reductions associated with various risk management alternatives. These decisions are based on risks associated with site-related contaminants and impacts resulting from remedial actions to reduce human health and ecological risks. The process is not a simple linear or sequential process but can be iterative, and some steps may not be necessary. ERA Steps concluding with SMDPs will be discussed with EPA during appropriate monthly project update meetings. When appropriate, technical memoranda will be submitted prior to the monthly meetings to expedite the decision making process during the meeting.

Step 1 Screening Level Problem Formulation

The initial step of the ERA process is screening level problem formulation. Problem formulation is based on existing site information regarding the environmental setting of the site, potential constituents of concern, contaminant fate and transport mechanisms, and contaminant toxicity to ecological receptors. The result of this step is a conceptual model that identifies potentially complete exposure pathways for ecological receptors of the site.

In 1992, USEPA contracted Malcolm Pirnie and CH_2M Hill for the performance of preliminary ecological assessment activities related to exposure to wastes associated with the former waste oil lagoon. These activities consisted of an endangered and threatened species assessment; a floodplain assessment; a wetland assessment; and an ecological risk assessment. As a result of these and other site-related activities, a summary report of RI activities was prepared (CH_2M Hill, 1996A). This USEPA contracted report and selected references therein provided information that was used for the ecological screening step in this ERA. In addition, reports containing ecological risk assessment information from the nearby Chemical Leaman site (Barnett, 1993) were also consulted.

General Conceptual Model

Based on the available information, a general conceptual model of the distribution and potential transport pathways of site contaminants has been developed (Figures 17 and 29). The two general primary source areas were the former lagoon area and the former tank farm/process areas. Most source materials in both areas (oil, sludge, tanks, etc.) have been removed. The residual chemical constituents on the BROS property are nearly completely covered with the fill material placed by the USEPA's lagoon remediation contractor.

The BROS property and the properties to the south and southwest were originally forest and farm upland areas. These properties were mined for sand using a water-based dredging technique which extended below the water table. The result of the mining activities was three ponds with silty/clay bottoms, one of which became the former BROS lagoon. The BROS lagoon overflowed its eastern banks following heavy rains associated with a hurricane in June of 1972.

Oil and water accumulated in Little Timber Creek Swamp adjacent to the former lagoon and in a smaller area just north of U.S. Route 130. The areas where LNAPL residuals remain in the sediment of Little Timber Creek Swamp appear to be associated with areas currently dominated by *Phragmites*, a common weed of disturbed areas. Little Timber Creek Swamp drains towards the northwest; however, the potential for sediment associated contaminants to be transported downstream is low due to the highly retentive nature of the Little Timber Creek Swamp resulting from no defined creek channel and a thick layer of organic matter covering the overflow residuals. North of U.S. Route 130, there is occasional tidal influence. However, a functional tidal gate north of Route 44 prevents significant tidal backflow and impairs immigration of fish to Little Timber Creek.

This ERA focuses on the three primary ecological systems of the BROS site: Gaventa Pond, Swindell Pond, and Little Timber Creek Swamp (Figure 29). The following sections of the ERA summarize the existing information regarding ecological characterization of these areas, constituents of potential concern in their associated media, and potentially complete exposure pathways for ecological receptors.

Gaventa Pond

Gaventa Pond is a 22 acre constructed freshwater pond located southwest of the former BROS lagoon. The pond was created as a result of previous sand mining operations, resulting in steep side slopes with very little littoral zone. There is no surface water connection between Gaventa and Swindell Ponds. Sand and gravel were removed until a clay layer was encountered. The pond is reported to have several small areas greater than 30 feet deep (CH_2M Hill, 1996A). Fish are reported to be present in the pond, but fish species information is not available.

Until dewatering lowered water levels in the BROS lagoon, water elevation in Gaventa Pond was lower than lagoon water elevation, indicating the potential for water movement from the lagoon to the pond by way of the ground water pathway. Prior to the lagoon remedial activities, oil from the lagoon seeped along piping that extended into the northeast corner of Gaventa Pond requiring a boom to be placed in this location to contain the oil. In 1990, three surface water samples were

collected from Gaventa Pond with one sample collected from within the area containing the oil boom; the boom has since been removed since no oil seeps remain. TPH concentrations were detected in two samples at 0.5 mg/ℓ and 18.5 mg/ℓ with the highest concentration detected from the sample within the boomed area. PCBs are the only organic constituent of concern in surface water of Gaventa Pond, detected within the boomed area at 135 μg/ℓ. The following metals were identified as potential constituents of concern in surface water by CH_2M Hill (1996): antimony, copper, lead and zinc.

Toluene was detected in two of the three sediment samples with the highest concentration of 0.14 mg/kg. Bis (2-ethylhexyl) phthalate (3.3 mg/kg) and dibutyl phthalate (0.22 mg/kg) were the only SVOCs detected in the sediment samples from Gaventa Pond. PCBs at a concentration of 2.2 mg/kg and TPH at concentrations of 22,619 mg/kg and 173 mg/kg, were detected in sediment samples from Gaventa Pond. Lead (42.5 mg/kg) was the only inorganic constituent identified by (CH_2M Hill, 1996A) as a constituent of potential concern in the sediments of Gaventa Pond. Chromium (39.2 mg/kg) and arsenic (17.3 mg/kg) were also present in the sediments at elevated concentrations.

Evaluation of current surface water and sediment quality will be performed as part of this ERA to evaluate the status of exposure pathways in Gaventa Pond. Based on existing data, complete exposure pathways potentially exist for direct contact with surface water and sediments for benthic invertebrates, direct contact with water an sediment for fish and through the aquatic and terrestrial food chains for constituents that bioaccumulate.

Swindell Pond

Swindell Pond is a 13 acre constructed freshwater pond located southeast of the former BROS lagoon. The pond was created as a result of previous sand and gravel mining operations, resulting in steep side slopes with very little littoral zone. Sand and gravel were removed until a clay layer was encountered. The pond is reported to be greater than 20 feet deep at its deepest point (CH_2M HILL, 1992b). Fish are reportedly present in the pond, but fish species information is not available. During extended periods of abundant precipitation, a direct connection exists between

Swindell Pond and Little Timber Creek Swamp to the east, but there is no surface water connection between Swindell and Gaventa Ponds.

There are no reported site releases to Swindell Pond. Until dewatering lowered water levels in the BROS lagoon, the water elevation in Swindell Pond was lower than lagoon water elevation but higher than Gaventa Pond, indicating a potential for ground water movement from the lagoon to the pond but not from Gaventa Pond. Analytical results of two surface water samples collected under USEPA's Phase 2 RI for the BROS Lagoon indicated that site-related constituent concentrations in surface water of Swindell Pond were insignificant. Several metals were detected in pond sediments at concentrations that exceeded screening values.

Evaluation of current surface water and sediment quality will be performed as part of this ERA to evaluate the status of exposure pathways in Swindell Pond. Based on the existing data, complete exposure pathways may potentially exist for direct contact with sediments for benthic invertebrates and through the aquatic and terrestrial food chains for constituents that bioaccumulate.

Little Timber Creek Swamp

Little Timber Creek Swamp is located east and north of the former BROS Lagoon. Little Timber Creek Swamp is a red maple forested wetland (swamp) that is fed and drained by Little Timber Creek; however, no defined channel exists through Little Timber Creek Swamp. The shrub and ground layer vegetation is dense in portions of the wetland, but unvegetated areas exist over saturated muck soils which are frequently inundated (CH_2M HILL, 1992b). Shallow ground water from the former process/tank area and former lagoon area probably discharges to Little Timber Creek Swamp between U.S. Route 130 and Route 295, at least during some portion of the year. In addition, during periods of low ground water elevations (late summer and relatively dry years), surface water may recharge shallow ground water. No information is available on the geology, hydrology, or ground water quality below the wetlands but these areas will be the focus of additional ground water assessment and water budget analysis tasks of this RI Work Plan. Visual observations indicated that previous lagoon overflow had disturbed the vegetative community of

the wetland, as evidenced by the replacement of native vegetation with opportunistic species (e.g. *Phragmites*) in an approximately 3 acre portion of this area.

Two federally-designated endangered or threatened wildlife species were identified in 1992 as being present along the Delaware River in general proximity to the site were the peregrine falcon and the bald eagle. The peregrine falcon and bald eagle are listed by the U.S. Fish and Wildlife Service and State of New Jersey as endangered and threatened, respectively. Little Timber Creek Swamp does not provide optimum habitat for these species due to the dense canopy vegetation impeding aerial predation and the lack of open water habitat of sufficient size to provide food sources. The habitat requirements (nesting and foraging) of these species will be evaluated in relation to the habitats where BROS COPECs are distributed. No threatened or endangered wildlife species were identified as potential site inhabitants (CH_2M HILL, 1992b). NOAA (1990) reported juvenile blueback herring were found in the lower portion of Little Timber Creek. The remedial investigation of the CLTL site reported suitable habitat for a bog turtle in Moss Branch Creek, which is a separate tributary of Little Timber Creek and not part of the BROS site. Portions of the wetlands south of Route 295 may provide acceptable habitat for bog turtle and will be surveyed for bog turtle presence during the receptor survey.

An evaluation of the functions and values of Little Timber Creek Swamp was performed by (CH_2M Hill, 1992a) as part of the initial site investigation activities using the Wetland Evaluation Technique (WET). WET evaluates the social significance, effectiveness and opportunity of seven primary wetland functions. The Little Timber Creek Swamp wetlands were ranked highly effective at performing the functions of sediment/toxicant retention and providing breeding and migration habitat for wetland wildlife. The high ranking for sediment/toxicant retention is the result of:

- the constricted outlet of the wetlands,
- the slow flow rate of water through the wetland,
- the long duration and extent of seasonal flooding, and
- the wide zone of vegetation.

The ranking for wildlife breeding is high if during the breeding season the wetland normally supports a notably great on-site diversity and/or abundance of water-dependent birds. The high effectiveness rating for water-dependent bird habitat is the result of:

- the wetland being greater than 5 acres in size,
- the availability of cover adjacent to the wetland,
- minimal human disturbance,
- no direct alteration,
- no salinity contamination,
- proximity to other wetlands,
- presence of muck substrate, and
- high vegetation/water interspersion.

The high effectiveness rating for wildlife migration is due to:

- the high vegetative diversity and interspersion,
- proximity to large agricultural areas,
- proximity to river coastline,
- wetland size greater than 5 acres,
- palustrine and estuarine systems within 5 miles of each other, and
- proximity to the Delaware River.

The site wetlands were ranked moderately effective at performing the functions of ground water discharge, floodflow alteration, sediment stabilization, nutrient removal/transformation, production export, and aquatic diversity/abundance. The moderate ranking for aquatic diversity/abundance is the result of:

- permanent inlets and outlets,
- palustrine systems with standing water, and
- restricted contributions from overland flows and sediment sources.

The most pivotal characteristics for aquatic diversity/abundance are substrate type, hydroperiod, and presence of potential toxicants. The site wetlands lack sufficient size, require greater water/vegetation proportions and a semi-permanent flooded condition to obtain a high ranking for aquatic diversity/abundance.

Site wetlands were ranked low for their effectiveness to recharge ground water and provide wintering wildlife habitat. The low wintering wildlife habitat ranking is the result of:

- the possibility of frozen water in the wetland for more than one month out of the year,
- lack of mudflats and emergent marshes in the area, and
- the presence of potentially toxic inputs to the wetland.

Benzene and PCBs were detected at elevated concentrations in surface waters of the wetland area. Elevated concentrations of cadmium, lead, zinc, TPH, and PCBs were detected in sediments of this portion of Little Timber Creek wetlands, primarily adjacent to the former lagoon location but also further into the wetland. Evaluation of current surface water and sediment quality will be performed as part of this ERA to evaluate the status of exposure pathways in Little Timber Creek Swamp. Based on the existing data, potentially complete exposure pathways exist for aquatic invertebrates, reptiles and amphibians for direct contact with surface water, sediment, and soil; terrestrial wildlife for direct contact with soils and surface water; and via bioaccumulation through the aquatic and terrestrial food chains.

Step 2 Screening-Level Exposure Estimate and Risk Calculation

A screening level exposure estimate and risk calculation is performed based on the complete exposure pathways identified as a result of the problem formulation task. The screening level exposure estimate and risk calculation step ends with a SMDP that (1) ecological threats are negligible; (2) the ecological assessment should continue to determine whether a risk exists; or (3) impacts are likely and a more detailed ERA is needed. The representativeness of the data collected during active lagoon seepage to current conditions is uncertain and the quality of data is not adequate to complete a detailed evaluation of the current constituents of concern. Removal

of primary source material, hydrologic changes resulting from elimination of the lagoon, and natural degradation processes may have substantially influenced current chemical concentrations in the environmental media. Therefore, preliminary risk calculations were not performed at this time but will be performed as part of subsequent ERA steps when data representative of current exposure points are available. Consequently, the screening-level exposure estimate and risk calculation was completed in relation to available standards and screening criteria. Conclusions related to requirements for additional steps for evaluation of Gaventa Pond, Swindell Pond, and Little Timber Swamp Creek, based on the existing data, are presented below.

Throughout this Work Plan, the term soil will be used for non-hydric soils and the term sediment will be used to describe materials covered by water at least 50% of the growing season (late April March to mid-September), as requested by USEPA in the second scoping meeting. In between these zones where there are hydric soils which are not inundated most of the growing season, site-specific screening concentrations and goals will be established based upon site-specific conditions relevant to the risk assessment, rather than using soil or sediment screening criteria.

Gaventa Pond

Based on the constituent concentrations in the surface water and sediment of the northeast portion of Gaventa Pond that exceed screening criteria and the presence of complete exposure pathways for a variety of ecological receptors, it is apparent that sufficient evidence exists for continuing the ERA for Gaventa Pond.

Swindell Pond

Several metals (arsenic, chromium, copper, lead, and zinc) were detected in pond sediments at concentrations slightly exceeding screening values (Table 2c). Although a transport mechanism from the former lagoon area to the pond has not been identified, the detections of site-related constituents that exceed screening criteria in pond media warrant further evaluation of exposures to pond media.

Little Timber Creek Swamp

Based on the elevated constituent concentrations in the environmental media of Little Timber Creek Swamp, the visible vegetation transitions in the spill area, and the presence of complete exposure pathways for a variety of ecological receptors, it is apparent that sufficient evidence exists for the continuance of the ERA for this area. However, the current representativeness of the data collected during active lagoon remediation and wastewater treatment plant discharge is questionable, and the quality of data is not adequate to complete evaluations of current constituents of concern. Therefore, preliminary risk calculations were not performed at this time but will be performed as part of subsequent ERA steps as new data becomes available.

Previous data collection efforts of USEPA were primarily conducted in the portion of Little Timber Creek Swamp between Route 295 and U.S. Route 130 (CH_2M Hill, 1996a). These sampling efforts did not identify the lateral extent of site-related constituent release. Therefore, sampling and ecological assessment will also be performed in a second portion of the swamp, north of the first area, bounded by U.S. Route 130 and Cedar Swamp Road.

The northern/downstream extent of site-related releases was not evaluated during previous investigations. Therefore, this third area of Little Timber Creek Swamp to be evaluated in this ERA drains to the north through a tidal gate and eventually into the Delaware River. Based on reduced constituent concentrations observed with increasing distance from the lagoon, site-related constituents are less likely to be detected above screening values in this area. The absence of site-related constituents in this area above screening values would support the conclusion of no effects on Little Timber Creek receptors below the tide gate north of Route 44. Should site-related constituents be detected at concentrations of concern in this area, additional evaluations of possible downstream effects may be conducted.

Scientific/Management Decision Point

At the end of Step 2 is a SMDP for the concurrence of risk assessors and risk managers on the results of the screening level problem formulation and risk calculation. The purpose of the SMDP is to decide whether the available information is 1) adequate to conclude ecological risks are

negligible, 2) not adequate to make a decision, or 3) indicates the potential for adverse ecological effects. It is apparent, based on the elevated concentrations of COPECs in portions of the site, that sufficient information exists to indicate a potential for adverse ecological effects. Based on the results of the problem formulation and screening level exposure estimate, the scope of a baseline risk assessment was developed to evaluate the risk associated with the identified complete exposure pathways associated with Swindell Pond, Gaventa Pond, and Little Timber Creek Swamp.

Step 3 Baseline Risk Assessment Problem Formulation

The baseline risk assessment problem formulation step establishes the goals, scope and focus of the baseline ERA based on the performance of the following activities:

- identifying potential ecological receptors and sensitive habitats
- identifying constituents of potential ecological concern;
- characterizing ecological effects of contaminants;
- identifying complete exposure pathways;
- developing a conceptual model with working hypotheses or questions that the site investigation will address; and
- selecting assessment and measurement endpoints.

Each of these activities was completed to the extent possible at this time. They are discussed in the following subsections. Components that are common to Swindell Pond, Gaventa Pond and Little Timber Creek Swamp are discussed collectively; components that differ between the areas are discussed separately for each area.

Identification of Potential Ecological Receptors and Sensitive Habitats

Ecological Receptors

The NJDEP and the US Fish and Wildlife Service were contacted previously and will be contacted for updated information regarding the potential presence of rare, threatened, or endangered species in the vicinity of the site. In addition, resident and transient wildlife species observed within a 0.5 mile radius of the site will be surveyed during additional site reconnaissance. The qualitative wildlife surveys are based on visual and auditory indicators, consisting of actual sightings, tracks, burrows, scat, browse or song. Trained field ecologists will collect data along five transects walked across the area of investigation. The transects will be oriented in a southeast to northwest direction and will cover the area beginning at the intersection of Interstate 295 and the exit ramp from Route 130 and ending at the eastern edge of Gaventa Pond. The transects will be spaced at 500 ft intervals and will begin at Interstate 295 and terminate at the drainage channel north of Route 44. Surveys will be performed between one half hour before sunrise and 10:00 AM and between 17:00 (i.e. 5:00 PM) and sunset to coincide with peak wildlife activity. Surveys will be performed during wet (Spring) and dry (Summer) conditions of the wetland to evaluate changing receptors and exposure pathways during different hydrologic conditions.

Surveys of aquatic receptors of the ponds and wetland areas will be performed to identify potential ecological receptors of each habitat. Three sediment grabs will be collected from each of the two ponds and up to 10 sediment grabs will be collected from wetland areas to evaluate the benthic invertebrate community at these locations. In addition, the fish community will be evaluated by electroshocking, seining, gill-netting, or trapping, as discussed in Section 7.8.5 of the SAP. Data collected along these transects will provide an indication of potential ecological receptors of the site.

On-Site Wetland Delineation Activities

The NJDEP has federal jurisdiction for freshwater wetlands in New Jersey except for those wetlands that are within 1,000 feet of tidal areas. Federal jurisdiction applies to some of the wetlands in the project area (Figure 27). Wetland boundaries will be identified in accordance with

the methodologies identified below. The wetland boundaries and their respective transition areas will be depicted on the site plan when completed.

In 1991, CH2M HILL delineated wetland boundaries in Little Timber Creek Swamp south of Rt. 130, an area totaling approximately 170 acres. However, the delineation did not cover properties north and south of the site and no record of the established boundaries is available. Therefore, under this RI effort, the boundaries of wetlands in the areas north and south of the site (Figure 27) will be delineated.

Surface water and sediment sampling under the RI will extend into Cedar Swamp. Cedar Swamp is a large wetland of relatively homogeneous vegetation that extends from Interstate 295 north almost to the Delaware River. A wetland boundary determination is required in this area for future evaluations of areal impacts. Therefore, the wetland boundaries of these portions of Little Timber Creek Swamp and Cedar Swamp will be delineated using procedures presented in the 1989 Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee, 1989). Due to the large size of the wetland area within the site, delineation efforts will focus on identifying the perimeter wetland boundaries north of Interstate 295, west and south of Repaupo Road and its intersection with an overhead power line, and north and east of the eastern banks of the Former Channel to the overhead power line. The northern wetland boundary will not be identified or delineated. The identified wetland boundaries will be flagged in the field for subsequent surveying. The wetland boundaries will be included on the cover type map of the site. Vegetative and hydrologic characteristics of the delineated wetland will be recorded to classify the wetland types.

A potential reference area has been identified for the project along little Timber Creek south of the site where surface water and sediment samples will be collected. Although characterization of this area is needed to support its selection as a reference area, approximate delineation of the boundaries of wetlands in the area is adequate because areal impact evaluation does not apply to this background area. However, the relative size of the area in relation to wetlands potentially impacted by site releases is important. Therefore the wetland boundaries of this area will be

qualitatively identified in this approximately 90 acre parcel based on limited field evaluations and data collection. Characterization of the wetland will be performed under separate activities associated with the selection of reference sites.

Identification of the Preliminary Constituents of Potential Ecological Concern (COPEC)

- The objective of this task is to focus the investigation on chemicals that have the greatest potential to impact ecological receptors. The identification of COPECs is based on detected concentrations in the environmental media, fate and transport potential, and toxicity to ecological receptors. An initial list of COPECs has been developed from the results of previous site investigations (see below). As previously discussed, the quality of the data and its representativeness of current conditions is uncertain. Therefore, the COPEC list will require modification upon review of new data collected during this investigation.

COPECs for the site will be identified by screening detected concentrations in the environmental media with regulatory criteria, standards, guidance values or toxicologic benchmarks. Surface water concentrations will be screened against New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B) and Ambient Water Quality Criteria (40 CFR Part 131). Consistent with USEPA guidance (USEPA, 1997b), in the absence of criteria or standards for surface waters, COPEC screening will utilize values such as Ecotox Thresholds (USEPA, 1996f) or toxicological benchmarks developed by Suter and Mabrey (1997). Sediment concentrations will be screened against guidance values developed by the Ontario Ministry of the Environment (Persuad, 1993) for freshwater sediments. Consistent with USEPA guidance (1997), in the absence of sediment guidance values from these sources for chemicals detected in sediments, screening values such as Ecotox Thresholds (USEPA, 1996f) or toxicological benchmarks developed by Hull and Suter (1997) will be used. However, all of these screening criteria are subject to revision between Work Plan approval and the data analysis phase of the RI. Chemicals with concentrations which exceed comparison values will be retained as COPECs.

COPECs of Gaventa Pond

Based on data generated during the investigation of the BROS lagoon, the preliminary COPECs associated with Gaventa Pond consist of PCBs, antimony, arsenic, chromium, copper, and lead (Table 2b). In addition, total petroleum hydrocarbons (TPH) will be included as COPECs because of the similarity of toxicity concerns associated with numerous individual constituents of TPH at the BROS site. These constituents were detected at elevated concentrations with respect to ecologically-based screening criteria or guidance. The analytical results of additional surface water and sediment samples collected from Gaventa Pond under this investigation will be evaluated to refine the list of COPECs.

COPECs of Swindell Pond

Based on data generated during the investigation of the BROS lagoon, no surface water COPECs were identified. The preliminary COPECs associated with Swindell Pond sediments consist of arsenic, chromium, copper, lead, and zinc. These constituents were detected at elevated concentrations with respect to ecologically-based screening criteria or guidance (Table 2). The analytical results of additional surface water and sediment samples collected from Swindell Pond under this investigation will be evaluated to refine the list of COPECs.

COPECs of Little Timber Creek Swamp

Based on data generated during the investigation of the BROS lagoon, the preliminary COPECs associated with Little Timber Creek Swamp consist of benzene, arsenic, lead, cadmium, chromium, copper, manganese, selenium, zinc, PAHs, and PCBs. In addition, total petroleum hydrocarbons (TPH) will be included as COPECs because of the similarity of toxicity concerns associated with numerous individual constituents of TPH at the BROS site. These constituents were detected at elevated concentrations with respect to ecologically-based screening criteria or guidance (Table 2). The analytical results of additional surface water, sediment and soil samples collected from the three areas of Little Timber Creek Swamp under this investigation will be evaluated to refine the list of COPECs.

Ecological Effects of Contaminants

The following sections summarize the toxicity discussions presented in (CH_2M Hill, 1996a) and Barnett (1993) of the preliminarily identified COPECs for the site. Analytical results of the sampling efforts described in this Work Plan will be evaluated, as previously discussed, to develop a final list of COPECs for the site. Upon finalization of COPECs, a literature search will be performed to focus and update the toxicity information presented below, based on identified exposure pathways and receptors. Particular emphasis will be placed on the mechanism of toxicity.

Copper

Copper can bioconcentrate in plant and animal tissue, but most animals effectively regulate copper uptake. The toxicity of copper is significantly affected by pH, alkalinity, and temperature. Hard water generally reduces copper toxicity, while low pH increases toxicity (Barnett, 1993). Leopard frog tadpoles exhibited reduced growth rates at concentrations of 0.06 ppm in water and concentrations greater than 0.38 ppm were lethal (Barnett, 1993). The reported LC50 for the bluegill is 1.25 ppm (Barnett, 1993). Significant mortality to Daphnia magna was reported to occur at 68 ppm in water (Barnett, 1993).

Lead

Lead is known to be toxic to mammals, but information on effects on wild species is relatively limited. Lead poisoning of birds, such as raptors, often results from the ingestion of lead shot in prey species. However, biologically incorporated lead is unlikely to reach exposure concentrations of lead shot ingestion (Eisler, 1988). The single dose LD50 reported for the guinea pig is 2,000 mg/kg body weight, and for the rabbit is 125 mg/kg body weight. The 30-day LC50 reported for the leopard frog is 105 mg/ℓ, but sublethal effects were observed at 25 mg/ℓ in water (Eisler, 1988). Demonstrated effects of lead exposure to plants include reduced photosynthesis, reduced mitosis, and reduced water absorption. Lead does not biomagnify in the food chain but can bioaccumulate. However, it is typically stored in hard tissue, such as bone and teeth (Eisler, 1988). The adsorption and toxicity of soluble lead to aquatic organisms is hardness dependent. Little information is available on the relative toxicity of the various forms of lead.

Eisler (1988) has reported lead to be toxic to freshwater species at water concentrations ranging from 140 µg/ℓ to 236,000 µg/ℓ, and chronic effects at water concentrations of 12 µg/ℓ to 83 µg/ℓ.

Zinc

Zinc in water can be acutely toxic to freshwater organisms at concentrations ranging from 90 µg/ℓ to 58,100 µg/ℓ, and chronic effects have been reported at levels from 47 µg/ℓ to 852 µg/ℓ (NOAA, 1991). In terrestrial species, chronic exposures to zinc can result in anemia, enteropathy, and kidney damage (Sileo and Beyer, 1985).

PCBs

PCBs are bioaccumulated by aquatic organisms, resulting in chronic sublethal effects such as reduced growth rates, reproductive inhibition, and other physiological alterations (Eisler, 1986). Acute toxicity in aquatic organisms ranges from 1 µg/ℓ to 10 µg/ℓ. Birds are generally more resistant to acute effects of PCBs than mammals. The LD50 in birds range from 604 ppm diet to more than 6,000 ppm diet (Eisler, 1986). The mink is the most sensitive mammal to PCB exposure, with sublethal effects on reproduction reported at 2 ppm in the diet (Eisler, 1986).

PAHs

PAHs are lipid soluble but do not biomagnify in food chains nor do they induce toxic effects in plants (Eisler, 1987). Information on toxic effects to wildlife is limited, but chronic feeding studies with mallards showed no effects up to 4,000 ppm PAHs in their diet. Embryotoxicity may occur to birds when PAHs are applied to eggshells. Effects in mammals are typically carcinogenic. The acute LD50 in rodents for benzo(a)pyrene is 50 mg/kg body weight, for phenanthrene is 700 mg/kg body weight, and for fluoranthene is 2,000 mg/kg body weight. Concentrations of naphthalene that were reported acutely toxic to aquatic organisms range from 50 µg/ℓ for a copepod to 150,000 µg/ℓ for mosquitofish. Toxicity of other PAHs can differ by an order of magnitude between species.

Total Petroleum Hydrocarbons

TPH is not a specific constituent but is composed of numerous volatile and semivolatile components. However, petroleum products in general have demonstrated a toxic effect on red maple saplings, indicating an intolerance of exposure to oil (Redington, 1994). The mechanism of TPH toxicity to red maple trees is probably direct physical toxicity.

Exposure Pathway Evaluation

An exposure pathway is the pathway by which a constituent travels from a source to a receptor. An exposure route is the point of entry of a constituent from the environment into a receptor. Physical and chemical characteristics of the environmental media influence the bioavailability of constituents. Analyses of surface water and sediment samples for pH, Eh, acid volatile sulfide, TOC, cation exchange capacity and grain size will be utilized to evaluate the partitioning and mobility of COPECs in and between media and to assess the bioavailability of the COPECs to ecological receptors. Surface water samples will be analyzed for total and dissolved constituents to support the evaluation of the bioavailable portions of COPECs.

Of the primary exposure routes (inhalation, ingestion and dermal absorption) ingestion or dermal absorption are the primary exposure routes at BROS, depending on the receptor. The most likely exposure pathways and exposure routes also are related to the physical and chemical properties of the constituents. An exposure pathway is not complete when a receptor cannot be exposed to the constituent, and incomplete exposure pathways do not require further evaluation (USEPA, 1997b). The following sections discuss the exposure pathway evaluation for Gaventa Pond, Swindell Pond, Little Timber Creek Swamp, and Cedar Swamp

Gaventa Pond

Gaventa Pond was formed as a result of sand and gravel mining, resulting in relatively steep and narrow shorelines with little submerged vegetation. Although the specific fish species inhabiting the pond have not been documented, their presence has been noted (CH_2M Hill, 1996a). Surface water in the northeast corner of the pond, closest to the former lagoon location, exhibited elevated concentrations of PCBs, lead and zinc during a period of active seepage to the pond.

Elevated levels of TPH, PCBs and zinc were detected in sediments of the pond. Constituent concentrations were historically highest in the immediate area of the historical seep from the BROS lagoon. With the remediation of the lagoon completed, the seep is no longer discharging to the pond and the boom has been removed. It is unlikely that concentrations have remained at their previous historical concentrations in Gaventa Pond.

Complete exposure pathways may exist in Gaventa Pond for reptiles, amphibians, fish and benthic invertebrates through direct contact with water and sediments. Complete exposure pathways may also exist for benthivorous and piscivorous wildlife that may feed in the pond. CH_2M Hill (1992) identified reptile, amphibian, mammalian, and avian inhabitants of the vicinity of the site. However, the specific inhabitants of Gaventa Pond were not identified. Of the potential receptors identified by (CH_2M Hill, 1992a) as being present in the vicinity of the site, benthic invertebrate or fish consumers consist of several reptiles and amphibians, raccoon, herons, egrets, waterfowl, osprey, rails, and kingfisher. The lack of significant littoral foraging areas would limit the use of the pond to primarily reptiles, amphibians, fish, waterfowl, osprey, and kingfisher.

Additional information regarding the current constituent concentrations in surface water and sediment of Gaventa Pond and the wildlife utilization of the pond will be used to refine the exposure scenarios. Upon review of the new analytical data and based on a receptor survey of the pond, a scientific/management decision will select one of the following: (1) if constituent concentrations are below site-specific levels of ecological concern, the ERA for the pond will not proceed further; (2) if constituents are found to be confined to a small portion of sediments in the pond, a decision may be made to remediate/excavate the material as part of the alternative analysis in the concurrent Feasibility Study; or (3) if elevated constituent concentrations exist throughout the pond, a screening-level hazard quotient will be calculated to evaluate whether further evaluation will be implemented at that time.

Swindell Pond

Swindell Pond was formed as a result of sand and gravel mining, resulting in relatively steep and narrow shorelines with little submerged vegetation. Although the specific fish species inhabiting the pond have not been documented, their presence has been noted (CH_2M Hill, 1996a) and will

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be further evaluated through a survey using seining and electroshocking as described in the SAP. No elevated concentrations of VOCs, SVOCs, PCBs, metals, or TPH were detected in surface water samples collected from the northeastern and northwestern portions of the pond. Sediments exhibited elevated concentrations of arsenic, chromium, copper, lead and zinc during the previous sampling event (CH_2M Hill, 1996a). Complete exposure pathways may exist for reptiles, amphibians, fish and benthic invertebrates through direct contact with sediments. Complete exposure pathways may also exist for benthivorous and piscivorous wildlife that may feed in the pond. CH_2M Hill (1992) identified reptile, amphibian, mammalian, and avian inhabitants of the vicinity of the site. However, the specific inhabitants of Swindell Pond were not identified. Of the potential receptors identified by (CH_2M HILL, 1992a) as being present in the vicinity of the site, benthic invertebrate or fish consumers consist of several reptiles and amphibians, raccoon, herons, egrets, waterfowl, osprey, rails, and kingfisher. The lack of significant littoral foraging areas would limit the use of the pond to primarily reptiles, amphibians, fish, waterfowl, osprey, and kingfisher.

Additional information regarding the current constituent concentrations in surface water and sediment of Swindell Pond, the hydraulic interrelationship between the pond and Little Timber Creek Swamp, and the wildlife utilization of the pond will be used to refine the exposure scenarios. Upon review of the new analytical data and based on a receptor survey of the pond, a scientific/management decision will select one of the following: (1) if constituent concentrations are below site-specific levels of ecological concern, the ERA for the pond will not proceed further; (2) if constituents are found to be confined to a small portion of sediments in the pond, a decision may be made to remediate/excavate the material as part of the alternative analysis in the concurrent Feasibility Study; or (3) if elevated constituent concentrations exist throughout the pond, a screening-level hazard quotient will be calculated to evaluate whether further evaluation will be proposed at that time.

Little Timber Creek Swamp

Little Timber Creek Swamp is a red maple dominated forested wetland that is fed and drained by Little Timber Creek, but with varying degrees of inundation and no developed channel. The primary biological functions of the wetland system are sediment/toxicant retention, nutrient

removal/transformation, and wildlife/aquatic life habitat. Within the wetland, the ability to support a fish community is questionable due to the intermittent flow conditions, shallow depths, and lack of flow in a defined channel. Few fish have been observed during site visits through the wetlands, even in the downstream reaches. Portions of Little Timber Creek, downstream of the tide gate, become more channelized and more likely support significant fish populations. The wetland provides habitat for a variety of reptiles, amphibians, birds and mammals. The absence of sizable open water areas and large fish minimize the potential for use by waterfowl and most piscivorous birds. Complete exposure pathways exist for aquatic organisms that directly contact surface water and sediment and for the herbivorous and carnivorous animals through the food chain. In addition, due to its sensitivity to petroleum products, red maple could be affected by exposure to residual LNAPL.

Surface water samples in the wetlands contained lead, zinc, and PCBs at elevated concentrations. However, no data have been collected since 1990, and the influence of the lagoon water treatment plant effluent and EPA sediment removal activities on the surface water concentrations is not known. Sediments of the wetlands contain elevated levels of TPH, PAHs, antimony, arsenic, barium, cadmium, lead, selenium, thallium, zinc, and PCBs. In general, there is a decreasing gradient of concentrations in the sediments as distance from the spill area increases (Figure 16). This gradient of contamination can be grouped into three relatively distinct zones, consistent with those identified by Suter (1995) (Figure 15).

(1) A *de manifestis* zone characterized by:

- change in habitat structure from forested swamp to emergent wetlands,
- the presence of residual LNAPL in sediment,
- COPECs present in surface water at concentrations exceeding surface water standards,
- the system capacity to process the organic residuals and sequester the inorganic constituents is limited by the concentrations of COPECs,

- concentrations of COPECs exceeding the relevant sediment screening assessment concentrations by ten times or more, and;

(2) an intermediate zone characterized by:

- no major change in habitat structure but possible shifts in plant community composition,
- low probability of isolated residual LNAPL in sediment,
- low probability of COPECs in surface water at concentrations consistently exceeding surface water standards,
- the system capacity to process the organic compound residuals and sequester the inorganic constituents is not significantly limited by the concentrations of COPECs,
- concentrations of COPECs exceeding relevant sediment screening assessment concentrations by between two times and ten times on average in some discrete sediment strata, and;

(3) a *de minimis* zone characterized by:

- no significant shifts in plant community composition,
- no residual LNAPL in sediment,
- background COPEC concentrations in surface water,
- excess capacity in the system to process the organic compound residuals and sequester the inorganic constituents,
- concentrations of COPECs ranging between two times the sediment screening assessment concentrations and 0.5 times on average the screening assessment concentrations or background, whichever is higher.

Exposure pathways are assumed to be complete for some of the ecological receptors in the *de manifestis* zone, probably complete for some receptors in the intermediate zone, and potentially complete for limited receptors in the *de minimis* zone. As a result of these differences, the intensity, type of sampling, and analytical parameters will vary among these three zones. The boundaries of these zones will be preliminarily identified based on the results of sediment screening characterization efforts proposed in this Work Plan. The ERA will focus assessment activities in the intermediate and *de minimis* zones to define the boundary between these two zones based on biological effects. Sediment COPEC concentrations in the biologically active surficial sediments will be correlated with sediment toxicity test results and macroinvertebrate community analyses to identify site-specific no observed effects levels. This evaluation will also consider COPEC concentrations, toxicity tests and macroinvertebrate community analyses in reference site media to support the identified no effect levels.

Cedar Swamp

No data has been collected from Cedar Swamp or depositional areas downstream of the tide gate. Under RI activities, media samples from these areas will be analyzed and compared against screening criteria to evaluate the downstream extent of contaminant migration and the potential for exposures to ecological receptors. The evaluation of this sampling effort will be a SMDP for whether additional ERA activities are required in this area.

Selection of Assessment Endpoints

An assessment endpoint is "an explicit expression of the environmental value that is to be protected" (CH_2M HILL, 1992b). Valuable ecological resources include those without which the preferred habitat and ecosystem would be significantly impaired, and those perceived as valuable by humans. Assessment endpoints are selected based on the ecosystems, communities, and/or species potentially present at the site. Appropriate selection and definition of assessment endpoints are critical to the utility of the ERA because they focus the ERA design and analysis.

Several preliminary assessment endpoints were selected to cover a range of valued ecosystem functions, as no one assessment endpoint could be adequate to assess a complex site, such as

BROS. The preliminary selection of assessment endpoints was based on the contaminants present and their concentrations, the mechanisms of toxicity, and the ecologically relevant receptor groups potentially exposed to the contaminant. Assessment endpoints for Little Timber Creek Swamp related to the primary biological functions of the forested wetland system, as identified in the WET analysis performed by CH_2M Hill (1992). The preliminarily defined assessment endpoints will likely be refined or different assessment endpoints will be added following the collection and review of the Phase I analytical data, the performance of the receptor survey, and the results of the hydrologic study. The results of these field efforts and any revisions to the assessment endpoints will be presented in a Technical Memorandum that will be submitted to USEPA for review and comment prior to the monthly meeting that will be used to discuss the SMDP.

Gaventa Pond

Due to its origin as a sand quarry, with steep sides and no significant littoral zone, Gaventa Pond has limited habitat value to fish. Emergent or submerged vegetation are absent in the littoral zones and the substrate is primarily clay and silt, which, when encountered, terminated the mining activities. Existing data, collected while the lagoon was active, indicate that PCBs, antimony, copper, lead, and chromium were present in sediment and/or surface water of Gaventa Pond. These COPECs can have lethal effects on sensitive macroinvertebrates and fish by direct contact or can bioaccumulate in tissue, resulting in a reduced forage base or a potential food chain exposure for wildlife feeding on these organisms. Therefore, the following assessment endpoints have been identified for the evaluation of Gaventa Pond:

- the health of benthic macroinvertebrates exposed by direct contact to COPECs in pond surface water and sediments;

- the health of fish exposed by direct contact to COPECs in pond surface water and sediments; and

- the health of terrestrial and aquatic wildlife consuming fish from the pond that may have bioconcentrated COPECs from pond media.

The current COPEC concentrations in the pond media, the habitat quality of the pond, and the density and number of macroinvertebrate and fish species present in the pond will be evaluated under ERA activities. The results of these efforts will be used to refine these assessment endpoints for the pond. Therefore, the results of the biotic survey activities will be presented in a Technical Memorandum for discussion with USEPA as a SMDP to evaluate the appropriateness of the selected assessment endpoints.

Swindell Pond

No constituents were detected above screening values in surface water of Swindell Pond. Arsenic, chromium, copper, lead, and zinc were identified as preliminary COPECs in pond sediments. As with Gaventa Pond, Swindell Pond originated as a result of mining operations and currently provides similarly low quality aquatic habitat. The absence of COPECs in surface water during conditions of higher contamination probability indicate that direct contact exposures to surface water by fish may not be required and that bioaccumulation in pelagic fish is not likely. Therefore, the assessment endpoint for Swindell Pond focus on exposures in the benthos in determination of the health of benthic macroinvertebrates exposed by direct contact to COPECs in pond sediments.

The current COPEC concentrations in the pond media, the habitat quality of the pond, and the macroinvertebrate and fish species present in the pond will be evaluated under ERA activities. The results of these efforts will be used to refine assessment endpoint selection for the pond. Therefore, the results of these activities will be presented in a Technical Memorandum for discussion with USEPA as a SMDP to evaluate the appropriateness of the selected assessment endpoints.

Little Timber Creek Swamp

Based on the results of the WET analysis, the primary biological functions of the Little Timber Creek Swamp are the provision of food, cover, and nesting habitat typical of a forested wetland, and the production of a food base for wetland and terrestrial wildlife. The COPECs (benzene, PCBs, TPH, PAHs, and several metals) in Little Timber Creek Swamp can have lethal effects

through direct contact and/or bioaccumulation through the food chain. Four specific assessment endpoints have been selected to evaluate the potential effects of chemical exposures on the Little Timber Creek Swamp and its inhabitants. They are identified below in the context of the functions described above. These assessment endpoints will assist in identifying the boundaries of the *de manifestis*, intermediate, and *de minimis* zones of ecological effects associated with the gradation of contamination from source areas to the reference condition. Due to Consent Decree limitations on the collection of new site data prior to the approval of the Work Plan, the assessment and measurement endpoints have been preliminarily identified based on the current understanding of existing information generated under previous investigations with different environmental conditions and through limited site inspections. Based on the results of chemical characterization of surface water and sediments of the swamp, the receptor survey, and hydrologic investigations tasks identified in this work plan, the assessment and measurement endpoints will be reevaluated and refined or changed to reflect the new site information, subject to USEPA review and approval. Throughout this Work Plan, the term soil is used for non-hydric soils and the term sediment is used to describe materials covered by water at least 50% of the growing season (April to mid-September), as requested by EPA in the second scoping meeting. In between these zones where there are hydric soils which are not inundated most of the growing season, site-specific screening concentrations and goals will be established based upon site-specific conditions relevant to the risk assessment, rather than using soil or sediment screening criteria. The results of the investigative efforts and any proposed changes to the assessment endpoints will be presented to the USEPA in a Technical Memorandum for discussion as a SMDP.

Assessment Endpoint 1: The Provision Of Food, Cover, and Nesting Wildlife Habitat Available In A Forested Wetland

One of the primary biological functions of the wetland areas of the site is to provide habitat for a variety of wetland-dependent and terrestrial wildlife species. The habitat value of the red maple swamp is primarily provided by the food, cover and nesting sites available in the canopy, understory, shrub, and ground cover strata. Impacts to this habitat could change the wildlife use of the area. The overflow from the former waste oil lagoon into Little Timber Creek Swamp in

1972 resulted in an obvious change in habitat from a forested wetland to a persistent emergent wetland (*Phragmites*) over 3 acres of the wetlands. This was due, at least in part, to the sensitivity of red maple to oil exposure (Redington, 1994). A hypothesis was formulated that shifts in vegetative community dominance and diversity are indicators of impacts of contaminant exposures and that these community shifts decrease along the declining constituent concentration gradation in the wetland sediments. Therefore, a population/community level assessment endpoint of the ERA is species dominance and diversity in the vegetative strata of Little Timber Creek Swamp.

Assessment Endpoint 2: The Provision Of An Abundant And Diverse Food Base For Wetland Wildlife

Another of the primary functions of the site wetland system is the support of higher trophic level organisms, including reptiles, amphibians, mammals and birds that forage on the aquatic macroinvertebrates present in the wetland. A hypothesis related to the macroinvertebrate community is that macroinvertebrate numbers may be related to the varying constituent concentrations in the environmental media. Therefore, the assessment endpoint is aquatic macroinvertebrate survival, diversity, and abundance.

The ability of Little Timber Creek Swamp to sustain a fish community is questionable due to the intermittent water regime (at least in dry years), the lack of a stream channel, and the relatively shallow water depths. The absence or presence of fish in Little Timber Creek Swamp is an important consideration when evaluating the potential ecological receptors such as migratory fish or piscivorous wildlife. If present in Little Timber Creek Swamp, these fish would be potential receptors to surface water and sediment direct contact exposures, as well as provide a possible mechanism for contaminant transfer through the food chain to a variety of avian and mammalian piscivorous receptors. Therefore, the results of the receptor survey in Little Timber Creek Swamp will be used to evaluate whether additional food chain exposure pathways exist in the swamp. The results of the receptor survey will be presented to USEPA in a Technical Memorandum and the need for additional assessment endpoints will be discussed as a SMDP.

Assessment Endpoint 3: No Health Effects on Predatory Birds consuming small mammals of Little Timber Creek Swamp

During the summer, much of Little Timber Creek Swamp shifts from aquatic habitat to terrestrial habitat as water levels recede. COPECs in sediments become potentially available to small mammals which consume invertebrates and contact the sediment. These small mammals can, in turn, be consumed by predatory birds, which can result in the bioaccumulation of COPECs to levels that effect the health of the bird. An evaluation of small mammal body burdens of COPECs will provide an indication of small mammal uptake by the consumption of macroinvertebrates and will also provide exposure point concentrations for predatory wildlife. Therefore, the assessment endpoint for the wetland food chain during dry periods is the health of predatory birds feeding on small mammals of Little Timber Creek Swamp.

Testable Hypotheses

Each of the assessment endpoints identified above will be related to the data collected across gradients of site-related constituents and compared with reference areas. However, cause and effect relationships will probably not be clearly established for any one constituent given the variety of COPECs and the range of hydraulic conditions at the site. The data will be utilized to establish correlations which will be evaluated in the context of the mechanisms of toxicity of the constituents and recent literature. Collectively, the patterns of biota change will be evaluated concurrently in a weight-of-evidence assessment to determine the extent and magnitude of the risks posed by the residual contaminants. The null hypothesis is that test areas are no different than reference areas for whatever parameter is measured. More specifically the testable hypotheses relate to whether the concentrations of site-related constituents cause adverse effects on the assessment endpoints. Null hypotheses and testable hypotheses are presented below for each assessment endpoint.

Gaventa Pond

- Assessment Endpoint 1: The health of benthic macroinvertebrates exposed by direct contact to COPECs in Gaventa Pond sediments.

Null Hypothesis: Exposure to COPECs in Gaventa Pond sediments has no effect on the health of macroinvertebrates.

Testable Hypothesis: Does exposure to COPECs in Gaventa Pond sediments have adverse effects on macroinvertebrates?

- Assessment Endpoint 2: The health of fish exposed by direct contact to COPECs in Gaventa Pond surface water.

Null Hypothesis: Exposure to COPECs in Gaventa Pond surface water has no effect on the health of fish.

Testable Hypothesis: Does exposure to COPECs in Gaventa Pond surface water have adverse effects on fish?

- Assessment Endpoint 3: The health of piscivorous birds consuming fish from Gaventa pond that have bioconcentrated COPECs from pond media.

Null Hypothesis: Consumption of Gaventa Pond fish has no effect on the health of piscivorous birds.

Testable Hypothesis: Does consumption of fish from Gaventa Pond have adverse effects on piscivorous birds?

Swindell Pond

- Assessment Endpoint 1: The health of benthic macroinvertebrates exposed by direct contact to COPECs in Swindell Pond sediments.

Null Hypothesis: Exposure to COPECs in Swindell Pond sediments has no effect on the health of macroinvertebrates.

Testable Hypothesis: Does exposure to COPECs in Swindell Pond sediments have adverse effects on macroinvertebrates?

Little Timber Creek Swamp

- Assessment Endpoint 1: Species dominance and diversity in the vegetative strata of Little Timber Creek Swamp.

  Null Hypothesis: Exposure to petroleum hydrocarbons has no effect on the vegetative species or diversity in Little Timber Creek Swamp.

  Testable Hypothesis: Does a shift in species dominance and diversity occur in the vegetative strata of Little Timber Creek along the TPH concentration gradient?

- Assessment Endpoint 2: Macroinvertebrate community diversity and abundance.

  Null Hypothesis: Exposure to COPECs in Little Timber Creek Swamp sediments has no effect on macroinvertebrate community diversity and species abundance.

  Testable Hypothesis: Do effects on macroinvertebrate community diversity and species abundance occur in Little Timber Creek along the contaminant concentration gradient?

- Assessment Endpoint 3: The health of predatory birds consuming small mammals of Little Timber Creek Swamp.

  Null Hypothesis: Consumption of small mammals of Little Timber Creek Swamp with bioconcentrated COPECs has no effect on predatory birds.

  Testable Hypothesis: Can consumption of small mammals exposed to COPECs in Little Timber Creek Swamp potentially have adverse health effects on predatory birds?

Scientific/Management Decision Point

At the conclusion of Step 3 is a SMDP where agreement will be reached on the COPECs, selected assessment endpoints, exposure pathways and risk hypotheses for the ERA. This SMDP has been partially completed through the review and comment of the previous draft version of this document and an ERA scoping meeting with USEPA, NJDEP, NOAA, and BROS Technical Committee members and consultants. At this meeting specific assessment endpoints were identified and have been included in this ERA for USEPA approval.

Step 4 Study Design and DQO Process

In Step 4, the conceptual site model is completed with the development of measurement endpoints. The conceptual site model is then used to design the study and develop data quality objectives. Some of the measurement endpoints selected for this ERA will be evaluated based on comparisons of measured characteristics on the site to each other and/or to reference areas. In addition, comparisons of measures at different locations on the site will assist in identifying the boundaries of the *de minimis*, intermediate, and *de manifestis* zones. The following sections identify the measurement endpoints, testable hypotheses, sampling design and rationale, and likely data interpretation methods. The specific field investigation methods are provided in the SAP. The ERA conceptual site model is summarized in the table on the following page.

ERA Conceptual Site Model

Secondary Source	Tertiary Source	Primary Receptor	Secondary Receptor	Tertiary Receptor	Assessment Endpoints	Measurement Endpoints
Gaventa Pond						
Ground water seepage to Pond from lagoon	Pond sediments	Benthic macroinvertebrates	Fish	Piscivorous birds	Benthic macroinvertebrates Fish Piscivorous birds	Concentration screening Toxicity testing Tissue sampling HQ modeling Community surveys
Swindell Pond						
Ground water seepage to Pond from lagoon (unconfirmed)	Pond sediments (uncofirmed)	Benthic macroinvertebrates	Fish	Insectivorous birds	Benthic macroinvertebrates Insectivorous birds	Concentration screening Toxicity testing Tissue sampling HQ modeling Community surveys
Little Timber Creek Swamp						
Lagoon releases to wetlands Ground water discharges to wetlands	Wetland sediments	Vegetation Macroinvertebrates	Small mammals	Predatory birds	Vegetation Macroinvertebrates Small mammals Predatory birds	Concentration screening Community surveys Toxicity testing Tissue testing HQ modeling

Establishing Measurement Endpoints

Measurement endpoints are measurable ecological characteristics that are related to the valued characteristic chosen as the assessment endpoint and can be measures of effects, measures of exposure, and/or measures of ecosystem and receptor characteristics. Measurement endpoints are typically numerical expressions of observations that can be statistically compared to a control or reference site to detect adverse responses to site constituents. Measurement endpoints in field studies are evaluated according to the probability they can be used to establish causal links between the site contaminants and the measurement endpoint response. Sampling of measurement endpoints is directly related to physical and chemical characteristics of the site. Measurement endpoints that are proposed for the evaluation of the identified assessment endpoints are discussed below.

Gaventa Pond

Three assessment endpoints were selected for impact evaluations in Gaventa Pond: 1) benthic macroinvertebrates exposed by direct contact to COPECs in pond sediments, 2) fish exposed by direct contact to COPECs in surface water of the pond, and 3) piscivorous birds consuming fish from the pond that may have bioconcentrated COPECs from pond media. These assessment endpoints will be re-evaluated based on the results of the receptor survey, hydrologic evaluations, and chemical characterization efforts being performed under RI efforts. The measurement endpoints identified for each assessment endpoint will be evaluated in a phased approach (not all concurrently), with the results of initial phases determining the need for further evaluation.

The measurement endpoint that will be used as the first phase of evaluation for the direct contact exposures for macroinvertebrates to sediments and pelagic fish to surface water consists of a combination of exposure measures and effects measures. The exposure measure consists of identifying COPEC concentrations in surface water and sediments of the pond for comparison to literature derived-effects levels for organisms observed in the pond. Comparison of surface water and sediment COPEC concentrations to toxicity endpoints is the effects measure that will complete the first phase of assessment. Exceedance of effects levels in the surface water or sediments is a SMDP which will require a risk management decision, or the performance of

community assessment or chronic toxicity tests on representative organisms as a second phase effects measure, or some other site-specific testing. For direct contact sediment exposures, sediment samples would be collected from pond locations representative of the identified COPEC concentrations and submitted to the laboratory for chemical characterization and chronic toxicity testing. Test organisms for the laboratory test would be identified based on macroinvertebrates identified in the pond during the receptor survey. For direct contact surface water exposures, surface water samples would be collected from pond locations representative of the identified COPEC concentrations and submitted to the laboratory for chemical characterization and chronic toxicity testing. Test organisms for the laboratory test would be identified based on fish species identified in the pond during the receptor survey.

Two measurement endpoints will be utilized to evaluate the food chain assessment endpoint for piscivorous birds in Gaventa Pond, if the initial evaluation of chemical data and biota survey information warrant. (1) COPEC concentrations in prey would be measured and (2) utilized in a food chain hazard quotient (HQ) model for a representative piscivorous bird, utilizing literature derived toxicity values as an effects measure. The quotient is expressed as a unitless ratio of a receptor's total daily intake of a chemical to the reported No Observed Adverse Effect Level (NOAEL). Total daily intake (TDI) is an estimate of the sum of chemical which may be consumed through forage. Daily intake for forage would be calculated using the range of site-specific data on chemical concentrations in site biota and receptor life history information such as ingestion rates, home range size, and body weight. Ingestion rate, home range, body weight, and dietary components would be obtained from published literature for the selected species. The area use factor (AUF) is based on the species home range in comparison to the size of the site. HQ results of less than 1 provide a good indication of no risks. However, HQ results greater than 1 will require a SMDP to determine if additional information to evaluate site-related effects and evaluate remedial options.

Swindell Pond

The assessment endpoint selected for impact evaluations in Swindell Pond was benthic macroinvertebrates exposed by direct contact to COPECs in pond sediments. This assessment

endpoint will be re-evaluated based on the results of the receptor survey, hydrologic evaluations, and chemical characterization efforts being performed under RI efforts.

The measure of direct contact exposure of macroinvertebrates to sediments consists of a combination of exposure measures and effects measures. The exposure measure consists of identifying COPEC concentrations in sediments of the pond for comparison to literature derived-effects levels for organisms observed in the ponds. Comparison of sediment COPEC concentrations to toxicity endpoints is the effects measure that will complete the first phase of assessment. Exceedance of effects levels in the sediments may require the performance of chronic toxicity tests on representative organisms as a second phase effects measure. For direct contact sediment exposures, sediment samples will be collected from pond locations representative of identified COPEC concentrations and submitted to the laboratory for chemical characterization and chronic toxicity testing. Test organisms for the laboratory test will be identified based on macroinvertebrates identified in the pond during the receptor survey.

Little Timber Creek Swamp

The measurement endpoints selected for each of the assessment endpoints for Little Timber Creek Swamp are presented below.

1 - *Dominance and diversity of the plant community of Little Timber Creek Swamp.*

The plant community of Little Timber Creek Swamp provides habitat for a variety of wildlife species. The type of swamp habitat is most strongly influenced by the ecologically dominant vegetation or keystone species of the various strata. Consequently, the species abundance and diversity of the different strata in site wetlands and reference areas will provide a direct measure of ecosystem characteristics based on measures of individuals in standardized sample plots laid out along similar hydrologic conditions. On the site, these plots will be established in the intermediate and *de minimis* zones to evaluate correlation between media concentrations and changes in the plant community. Species dominance and vegetative diversity in reference areas and along sediment COPEC concentration gradients on the site and will provide measures for comparison and interpretation of plant community effects of sediment COPEC exposure. In the

de manifestis area, analysis of the plant community will be limited to faunal richness because the area is currently an emergent herbaceous wetland dominated by Phragmites, to the exclusion of nearly all other plant species.

The assessment will be designed to select survey sites of similar hydrology, soil types, canopy cover, and elevation so that statistical differences in plant community characteristics are reflective of exposure to sediment COPECs and not the result of physical location differences (Section 7.8.2 of the SAP).

2 - *Macroinvertebrate survival, abundance, and diversity*

The survival of macroinvertebrates in Little Timber Creek Swamp is important to biological processes and wetland dependent wildlife. The first measurement endpoint related to macroinvertebrates is a comparison of COPEC concentrations in the sediments to screening criteria. Exceedance of sediment screening criteria is a SMDP, to identify what additional measures are required to evaluate the macroinvertebrate community.

The abundance and diversity of aquatic macroinvertebrates could be directly measured along the contamination gradient across the site and in the reference areas. Matching of physical characteristics in the microhabitats sampled is crucial to assigning differences to sediment COPEC exposures and not natural habitat variability. Comparisons of macroinvertebrate numbers and taxa across the chemical concentration ranges of the site and with the reference site will be an indicator of the availability of forage for insectivorous bird receptors of the swamp. Identification will be to the order level rather than family or genus due to probable dominance of diptera species in the swamp areas away from highway culverts. If sufficient quantities of macroinvertebrates are collected for statistical evaluation, USEPA's Rapid Bioassessment Protocol (USEPA 1989) may be used to evaluate the macroinvertebrate community.

If community analyses indicate potential effects, sediment toxicity tests along sediment contamination gradients of the swamp will provide an effects measure for macroinvertebrate survival. Sediment sample locations for laboratory toxicity testing and collocated sediment

chemical characterization samples will be selected to represent the contamination gradient across the site, based on the results of the sediment field screening. Test organisms for the laboratory test will be identified based on macroinvertebrates identified in the swamp during the receptor survey.

3- *The health of predatory birds feeding in Little Timber Creek Swamp.*

COPEC exposures to predatory birds is a function of the COPEC concentration in their prey. The exposure measure related to COPEC concentrations in the predatory bird's forage base will be accomplished through laboratory analyses of small mammals. The appropriate bird species endpoint receptor and its primary forage organisms will be identified based on the results of the receptor survey. The small mammal COPEC concentrations will be utilized in a food chain hazard quotient (HQ) model for the representative predatory bird utilizing literature derived toxicity values as an effects measure. As previously discussed, HQ results of less than 1 provide a good indication of no risks. However, HQ results greater than 1 will be a SMDP to evaluate what additional information would be required to evaluate actual effects. The assessment and measurement endpoints will be reevaluated when additional data are available.

Study Design

The study is designed to utilize multiple lines of evidence to answer questions and hypotheses concerning the assessment endpoints. The overall assessment is based on the conceptual models presented above.

Gaventa and Swindell Ponds

The assessment of Gaventa and Swindell Ponds is a phased evaluation beginning with sediment and surface water COPEC concentration comparison with ecologically based screening criteria. The potential for adverse effects related to direct contact with elevated COPEC concentrations in pond media will be evaluated in context of the identified biological communities of the ponds to determine whether additional assessment endpoints require evaluation. Surface water and sediment toxicity testing, macroinvertebrate community analyses, and/or tissue sampling may be implemented if endpoint values are exceeded in the environmental media and pond habitats are found to be physically capable of supporting significant macroinvertebrate and/or fish populations. Chemical characterization of tissue samples will be used for HQ evaluation of exposures to

predatory wildlife. HQ results less than 1 indicate a low potential for risk to the modeled receptor.

Little Timber Creek Swamp

Although some previous sampling has been completed in the wetland area, the horizontal and vertical distribution is largely undocumented due to a lack of sampling data, but also as a result of the analytical detection problems associated with the wetland sediments. The study components consist of:

- mapping of the dominant vegetation patterns (overstory and understory) and hydrology (depth, flow rates, and flow patterns) utilizing sampling locations distributed perpendicular to the dominant stream flow conditions. Flow patterns and relative velocities will be determined by dye testing; see SAP for details.

- a quantitative vegetation survey along sediment contamination gradients; see SAP.

- preliminary mapping of the *de manifestis* zone based on aerial photographs and on-site field observations to visually determine the extent of LNAPL residuals in the sediment.

- in the *de manifestis* zone (Figure 26), the sampling will be limited to defining the vertical extent of contamination and characterize the sediment for evaluation of remedial alternatives.

- outside the *de manifestis* zone (Figure 26), sampling surface water, ground water, and sediment will be conducted to determine: the vertical and horizontal distribution of contaminants, the potential movement of contaminants from various portions of the site in surface water, the relationship of sediment contamination to ground water contamination (Figure 17, cross section into the wetlands), the environmental fate of the residual constituents, and which receptors contact the residual lagoon constituents. The sediment sampling locations extend out radially from the *de manifestis* zone (Figure 26) and are designed to establish horizontal concentration gradients, as well as vertical distribution.

Sediment samples will be collected from two discreet zones: 0 - 1 inch, and 0 - 6 inches for evaluations of COPEC exposure point concentrations and for comparison to screening criteria. Surface water sample locations were selected to measure concentrations and sources of runoff related to differing sediment concentrations, downstream locations to determine potential transport, and collocated with ground water monitoring wells to evaluate the discharge/recharge dynamics of surface water and ground water; see the SAP for details.

- toxicity testing of sediments along the contamination gradient between the *de manifestis* and *de minimis* zones after the initial screening of sediment concentrations and analysis of sediments for the complete list of COPECs.

- surveying and chemical analysis of wetland biota tissue samples, some concurrently with sediment sampling, to evaluate macroinvertebrate community characteristics and to identify exposure point concentrations for upper food chain receptors.

The current scope of work will lead to a substantial reduction of uncertainties and a robust weight-of-evidence evaluation, especially after completion of the second phase of ecological assessment sampling. In addition, components of the proposed study evaluate the direct toxicity to the dominant plants of the red maple swamp and benthic macroinvertebrates of the Gaventa Pond and wetland habitats. Also, the receptor survey and biological tissue chemical characterization will provide site-specific information on bioaccumulation and food chain effects. Comparisons of effects data across the contamination gradient from the site and with the reference condition will enable the identification of the boundaries of the *de manifestis*, intermediate, and *de minimis* zones for risk management decisions.

Reference Site Selection Process

The reference condition provides the baseline for comparisons with site observations to determine if chemical exposure has caused an environmental effect. Reference sites must be selected to be as similar as possible to physical and biological conditions at the site prior to constituent releases so that differences can be attributed to chemical exposure. The more closely the reference site

resembles the site, the more defensible the conclusions will be based on a comparison of the two (USEPA, 1996f). In this ERA the reference condition will provide 1) background concentrations of inorganic compounds in environmental media, 2) undisturbed maple swamp wetland vegetative community characteristics, 3) undisturbed macroinvertebrate community characteristics , and toxicity test controls.

USEPA guidelines for the selection of reference sites, in order of importance, consist of the following:

- Areas within the same ecoregion,
- Areas with no impoundments on associated streams and rivers,
- Areas with no known discharges or site contaminants,
- Areas with no known spills,
- Areas with low human population density,
- Areas with low agricultural activity,
- Areas with low road and highway density,
- Areas with minimal nonpoint source problems.

Additional characteristics of ideal reference sites include (USEPA, 1996):

- extensive natural vegetation representative of the region;
- a natural hydrograph;
- natural color and odor of water on the site; and
- presence of biota that are representative of the region and derive some support from wetland ecosystems.

Little Timber Creek Swamp is located east and north of the former BROS Lagoon. Little Timber Creek Swamp is a red maple forested wetland (swamp) that is fed and drained by Little Timber

Creek; however, no defined channel exists through Little Timber Creek Swamp. The shrub and ground layer vegetation is dense in portions of the wetland, but unvegetated areas exist over saturated muck soils which are frequently inundated (CH_2M HILL, 1992b). Little Timber Creek Swamp is surrounded by major interstate roadways and agricultural areas which necessitate inclusion of these characteristics in reference sites to establish the reference condition. The process of selecting areas representative of the reference condition for Little Timber Creek Swamp utilized a phased approach, in which increasingly narrower criteria were used to screen numerous potential reference areas until the best available locations were selected. The first phase consisted of a review of aerial photographs and regional maps covering the vicinity of the BROS site to identify potential reference areas based on similarity in size and location in the watershed. Potential reference sites were identified within the Little Timber Creek watershed, the Repaupo Creek watershed, the Raccoon Creek watershed, and the Game Creek watershed. Additional off-site locations were considered during the scoping process, at the request of EPA. No potentially appropriate reference sites were identified in the area covered by the Woodbury and Woodstown quadrangles. A total of 25 potential reference areas were identified by this effort (Figure 28).

The second phase in the reference site selection process consisted of preliminary field visits to the 25 potential sites. Several of these sites were visited by agency representatives during a site visit in April 1997 and photographs of others were discussed during the April 17, 1997 scoping meeting. The criterion used to preliminarily screen potential sites during site visits was the water regime. Of the 25 potential reference sites, 10 sites (Sites 10, 11, 12, 13, 16, 18, 19, 20, 21, and 24) were eliminated because their tidal influence resulted in water regimes much different from the seasonal flooding of the site wetlands. Four sites (Sites 14, 17, 23, and 26) were eliminated because they were channelized streams without fringe wetlands and three sites (Sites 22, 25, and 27) were eliminated because they were dry (Figure 28).

The remaining potential reference sites had similar water regimes to site wetlands. Final criteria for reference site selection were proximity to areas of investigation, similarity in physical and biological characteristics, and locations either upstream and/or at the point where concentration of site-related constituents will be lowest or not non-detectable, consistent with USEPA guidance

(1996; [Eco Update 2(4)], 1997). The remaining potential reference sites for the BROS site were further evaluated through the collection of qualitative characteristic information and comparison to site conditions. A summary of the observed potential reference site characteristics is presented in the table below.

Comparison Of Potential Reference Areas And Site Reference Area Selection Criteria

Location	Site	2	3	4	5	6	7	9	15
Distance from site (ft)	0	3000	1500	2500	3000	3000	4000	1000	15000
size (acres)	70	40	10	30	3	6	20	10	20
dominant canopy species	Rm	Rm	Rm	Rm		W	Rm	Rm	Rm
degree of canopy closure (%)	80	90	85	75		10	90	65	80
dominant shrub species	Bb, Aw	Aw, Sb	Al, Bb	Al, Sb		W	Gb	Aw, Sb	Aw, Sb
degree of shrub canopy (%)	70	70	80	65		10	20	60	70
dominant ground cover	Sc, Sf	Sc, Sf	Sf	Sf, Aa		G	Gb	Sc, Sf	Sf, Sc
percent ground cover	20	35	10	30		50	<10	20	40
soil type	Mu	Mu	Mu	Mu	Mu	Mu	Mu	Mu	Mu
elevation	10	10	10	10	10	10	10	10	10
inlet (Y/N)	Y	Y	N	N	N	Y	N	Y	Y
outlet (Y/N)	Y	Y	N	N	N	Y	N	Y	Y
water depth (inches)	0-6	0-8	0-8	0-6	>12	0-12	0-8	0-10	0-12
percent water cover	20	20	10	45	100	50	50	35	30

Rm - Red Maple
Aw - Arrowwood
G - Grasses
Mu - Muck
W - Willow
Sb - Sweetbay
Sc - Skunk cabbage
Aa - Arrow arum
Bb - Blueberry
Gb - Greenbriar
Sf - Sensitive fern
Note: All measurements based on ocular estimates

Based on the evaluation presented above, sites 2, 9, 4, 3, and 15 were identified to be potential reference sites because of similar water regimes, their locations in the same watershed (except for Site 15), and similarity in physical and biological characteristics to the site. However, their proximity to the site provides a potential for some contaminant influence from the site at some of these locations. Therefore, the surface water and sediment quality of these areas will be characterized during RI media characterization efforts. Six sediment/soil samples and one surface water sample will be collected from the five potential reference sites and analyzed. The results of the analyses from the areas in proximity to the site (Sites 2, 3, 4, 9) will be compared to the results from Site 15 and presented to the USEPA for review and acceptance of the proposed approach for identifying a reference condition. Similar constituent concentrations to Site 15 will

support that the other potential locations have not been chemically impacted by the site and that inorganic constituent concentrations and biological assessments of these areas will provide reference conditions for site evaluations. This approach is consistent with ERA guidance (USEPA, 1996f). The suitability of the reference areas for use in establishing a reference condition for the site will be reevaluated based on the sampling data from the reference areas, the results of the biota surveys and inspections of wetland study areas that will be conducted as part of the Phase 2 RI, and reexamination of the assessment and measurement endpoints. This reevaluation will be summarized in a Technical Memorandum for USEPA review and approval.

In addition to chemical characterization, dye testing will be performed in the site wetlands to evaluate potential migration pathways of site-related constituents through the surrounding wetlands. The dye study will provide additional information for the final selection of reference areas for Little Timber Creek Swamp. USEPA approval of the reference sites will be requested prior to initiation of additional ERA activities.

The reference condition will also be defined by the lack of biological effects demonstrated towards the low end of the contamination gradient from the site. Macroinvertebrate communities or toxicity tests that have consistent results over decreasing constituent concentrations will indicate that natural conditions, and not site-related chemicals, are the major influence on the evaluated characteristics.

Data Quality Objectives

Data Quality Objectives (DQOs) are employed throughout the development of the Work Plan to ensure that the type, quality, and quantity of environmental data to be collected are adequate to support the intended application (USEPA 1997). DQOs are a major consideration in this ERA due to the difficulties in analyzing sediments high in natural organic matter, iron and manganese, and relatively high concentrations of petroleum residuals in some portions of the wetlands. USEPA's contractor encountered substantial difficulties in their analysis of wetland sediments (CH_2M Hill, 1996). Accordingly, site-specific DQOs have been developed with these considerations taken into account, as described in the QAPP.

DQOs have been incorporated into the problem formulation phase of the ERA process. Assessment and measurement endpoints of this ERA require the collection of a variety of data, including chemical characterization of surface water, sediment, and biological tissue; vegetative and macroinvertebrate community characteristics; and surface water and sediment samples for bioavailability evaluations through toxicity testing. These data will be collected in accordance with the sample collection protocols presented in the FSAP and analyzed, as appropriate, in accordance with QA/QC requirements presented in the QAPP. Data is scheduled for collection during wet and dry periods of the site to evaluate exposures to ecological receptors under different exposure pathways.

Statistical Considerations

Various statistical methods will be utilized to evaluate the data relative to concentration gradients, reference areas and different zones of contamination. For example, parametric and non-parametric trend analyses can be evaluated using linear and non-linear regression analyses. Indices of diversity and dominance can be compared between site locations along the gradient of contamination as well as with the reference condition using multivariate statistical techniques such as ANOVA or detrended correspondence analysis (DCA) to determine community similarities. The number of samples in each area was selected, in part, to ensure statistical methods can be employed. However, it is important to note that a substantially significant difference relative to a control or reference area does not necessarily imply an ecologically significant difference (USEPA, 1997b). In general, this assessment preliminarily proposes that greater than 30% difference between the test area and the most similar reference areas for that particular measurement parameter be used to evaluate a significant change in measurement parameters that may be related to site constituents. Consequently, the *de minimis* areas will vary 30% or less from approximate reference areas. Intermediate zones will vary 30 to 60%, and *de manifestis* areas will vary 60 to 100%. The actual percent difference may vary based on the most recent literature, USEPA guidance, and discussions with the USEPA. The entire weight-of-evidence is used to draw conclusions as to whether a difference is ecologically significant.

Scientific/Management Decision Point

The end of Step 4 is a SMDP to evaluate the measurement endpoints, site investigation methods, and data reduction and interpretation techniques to evaluate site-related ecological risks. This Work Plan provides the mechanism for a SMDP for USEPA to review and comment on the study design, including measurement endpoints, site investigation methods, and data reduction and interpretation techniques. Based on USEPA's review, the ERA design can either be accepted or additional discussions may be held to refine objectives and methodologies to the agreement of all parties.

Step 5 Field Verification of Sampling Design

The objective of this step will be to verify that the ERA study design is appropriate and implementable at the site by visiting the site and evaluating sampling methodologies, locations, and exposure pathways. Step 5 has been initiated but is not yet complete. Aspects of the study to be verified consist of the following:

- The preliminary evaluation of fish utilization of Little Timber Creek Swamp will be performed during this step by evaluating fish presence and habitat quality based on qualitative sampling and observations of water depth, flow, cover, and substrate. Appropriate fish sampling methods will be evaluated as part of this effort.

- The species, densities, and habitat preferences of wetland macroinvertebrates will be identified to verify the selected macroinvertebrate sampling methodology and to evaluate the diversity of macroinvertebrates in the wetland sediments.

- The presence of terrestrial invertebrates will be evaluated for terrestrial food chain exposure potentials during dry periods, defined as no standing water at the surface for more than 10 days.

- The habitat quality, fish community, and invertebrate community of Swindell Pond and Gaventa Pond will be qualitatively evaluated to identify potential receptors and food chain exposure pathways.

- Sediment sampling methodologies will be tested in a variety of pond and wetland sediments to evaluate appropriateness, efficiency, and applicability.

- Any other sampling questions that may arise during the field verification process.

Sampling changes resulting from observations made during Task 5 efforts will require revision to the SAP and approval from USEPA.

Scientific/Management Decision Point

The SMDP for the field verification of the sampling design is the final approval of the ERA design by USEPA. Any changes to the scope of the ERA or sampling methodologies resulting from observations during the field verification will be presented to USEPA in a revised ERA Work Plan for review and approval.

Step 6 Site Investigation and Analysis Phase

Information collected during the site investigation is used to characterize exposures and ecological effects. The site investigation will include all of the field sampling and surveys that have been identified in Steps 1 through 5 of the ERA process. Site investigation tasks are presented in the SAP. Exposure characterization utilizes data collected during the site investigation to model exposures and effects to ecological receptors in the context of the conceptual site model. Site-specific data obtained during the site investigation replace assumptions and reduce uncertainties of the screening level analysis.

Schedule

The schedule for the ecological evaluation is a component of Phase 2 RI/FS activities (Plate 1), and will be conducted concurrently with other activities. However, the biota sampling and measurements included in the scope of work are season sensitive and exposure evaluations are required for wet and dry wetland conditions. Most of the work must be conducted between May and October. Therefore, the schedule of activities will be evaluated after Work Plan approval.

Scientific/Management Decision Point

As the results of the first phase of chemical characterization efforts for surface water and sediments become available and receptor surveys have been completed, decisions will be made with USEPA regarding current conditions in Gaventa and Swindell Ponds and whether the potential for unacceptable risk exists in these habitats that warrant further evaluation. In addition, the status of the fish community of Little Timber Creek Swamp will be defined so that decisions regarding the need to evaluate other potential exposure pathways in the swamp can be made. Analytical results of media samples collected from Cedar Swamp and its outlet stream will be evaluated to determine if additional downstream sampling is required to define the downstream extent of site-related COPECs. At this point the need for and scope of further investigations, including toxicity testing and tissue analysis, will be developed and presented to USEPA. Any proposed changes to the study will be presented to USEPA in a Technical Memorandum for review, comment, and approval.

Step 7 Risk Characterization

In the risk characterization task, the information on exposure and effects will be integrated into a statement about the risks to the assessment endpoints established during problem formulation. A weight-of-evidence approach will be used to interpret the various studies and evaluate the relation to the assessment endpoints. The risk characterization presents the results of risk evaluations within the constraints of the associated uncertainties.

Risk characterization consists of risk estimation and risk description. Risk estimation describes inferences that are made from measurement endpoints to assessment endpoints. Risks to pond receptors will be evaluated based on the results of media COPEC concentration comparisons to screening values, sediment and surface water toxicity test results, and HQ modeling using tissue sample results from the ponds. Toxicity test results for pond media provide an indication of risk levels within the confines of the uncertainty associated with differences between laboratory and natural system condition differences. Food chain models using site-specific tissue data and life history information for the endpoint receptor that result in HQs of greater than 1 provide an estimate of food chain risk. The potential effects to receptors of the COPECs detected in the

separate areas (i.e. Gaventa Pond, Swindell Pond and the Little Timber Creek Swamp) will be evaluated both individually by area and as groups where receptors are likely to use more than one area.

In Little Timber Creek Swamp, risk estimates will be developed based on results of media sample COPEC concentrations compared to screening values, macroinvertebrate community analyses, surface water and sediment toxicity tests, and tissue sampling along contamination gradients to demonstrate on-site exposure-response functions. The results of these evaluations will be mapped with chemical data to define the relationship between contamination levels and biological effects. This relationship will be used to define the boundaries of the intermediate zone for risk management decision purposes.

The risk description provides information for interpreting the risk results and identifies a threshold for adverse effects on the assessment endpoints. In Little Timber Creek Swamp, levels of sediment contamination below which no further improvements in the assessment endpoint are observed or expected can be identified from the gradient of ecological effects along a contamination gradient. In addition, threshold values for upper food chain receptors can be back-calculated using media-biota accumulation factors derived from media and tissue collocated samples.

Step 8 Risk Management

Risk management balances risk reductions associated with cleanup of contaminants with potential impacts of remedial actions themselves (USEPA 1998). Risk managers evaluate several factors to decide whether or not to clean up a site to within the range of threshold values identified by risk assessors. Factors to be considered include protection of human health and the environment; compliance with ARARs; long term effectiveness; reduction of toxicity, mobility, or volume of hazardous waste; short term effectiveness; implementability; cost; state acceptance; community acceptance; and ecological impacts. The selection of remedial alternatives may require tradeoffs between long-term risk posed by exposures of ecological receptors to residual contaminants and

short-term impacts associated with remedial actions. Remedial activities influencing ground water can influence the hydrology of surrounding wetlands resulting in habitat impacts.

For the BROS site, some remedial actions will probably be necessary for the *de manifestis* area (Phragmites and LNAPL residuals in sediment) resulting from the BROS lagoon overflow and probably a limited area in the northeast corner of Gaventa Pond. Remediation in portions of the forested wetland habitat of Little Timber Creek Swamp must be evaluated by risk managers with regard to the long-term habitat disturbances and risk reduction benefits if mature trees are removed or water levels are reduced. Low residual concentrations of constituents in wildlife habitats can be left in place and mitigated by habitat enhancements in adjacent areas. Such activities often result in overall environmental benefits, as sensitive areas are left undisturbed and low quality areas are managed for specific environmental goals of a region. These are some of the considerations which will be evaluated in the risk management step.

6.7 Task VII - Remedial Investigation Report

6.7.1 Activity 1 - Draft Remedial Investigation Report

The RI Report will be submitted to the USEPA in draft form in accordance with the schedule presented in Section 8.0. This report will summarize results of field activities to characterize the site, sources of contamination, the distribution of COPCs, which may include delineation of discrete areas of concern or "hot spots", and the fate and transport of COPCs. In addition, the data presented in the Site Characterization Summary Report will be considered, during the preparation of the RI Report. Only information from the Phase II Summary Report that contributes to technical observations and conclusions will be presented in the RI report.

Additionally, the RI report will contain the following information:

- the procedures used in the field if the procedures differed from the procedures specified in the SAP because of unanticipated conditions;
- data summaries, tables and figures for the results of the field activities;

- results of data validation results;
- one copy of the laboratory analytical data;
- maps, cross sections, and charts illustrating the results of the data collected;
- copies of the surveyor's field notes; and
- discussion of the results.

6.7.2 Activity 2 - Final Remedial Investigation Report

Upon receipt of the USEPA's comments of the Draft RI Report, revisions will be made and the RI Report will be submitted in final form.

6.8 Task VIII - Development of Remedial Action Objectives and Screening of Remedial Alternatives

6.8.1 Task VIIIA - Development and Screening of Remedial Alternatives

A preliminary identification of remedial alternatives was presented in Section 4.0 of this Work Plan, based upon the types of risks potentially posed by the site, a screening of remedial technologies and process options, and initial evaluation of remedial action objectives. The preliminary remedial action objectives (PRAOs) and the preliminary remedial alternatives will be refined throughout the RI/FS, based upon new data and the iterative risk assessment effort. The goal of this process is to develop a range of remedial alternatives that address the AOCs and hot spots at the site and meet the requirements of the NCP. The range of alternatives will include treatment options that vary in the types and degree of treatment, the amount treated, the manner in which long-term residuals or untreated wastes are managed, and the timeframe to achieve the PRAOs. Remedial alternatives will be developed and screened for all areas of the site identified during the human health or ecological risk assessment as posing significant risk to potential receptors. This preliminary screening considers effectiveness, implementability and costs of the remedial technologies and process options.

For this task, effectiveness is treated as the measure of overall short- and long-term performance in eliminating, reducing, or controlling the current and potential risks at the site (USEPA, 1998f). Implementability screening considers the degree of difficulty with construction and/or operation; including technical, administrative and logistical problems, and the time required to complete the remedy. Cost considerations include construction and O&M costs over a specific period of time. Cost evaluations will be completed using *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a), the NCP and other relevant guidance. For the screening of remedial alternatives, the cost estimates will be completed to the degree necessary to make comparative evaluations between alternatives. The level of detail and accuracy of cost estimates will be sufficient to ensure that cost decisions between alternatives are sustained as the accuracy of the estimates improves beyond the screening process (i.e. in the detailed analysis of alternatives). For purposes of estimating costs, long term O&M costs will be calculated for a period of up to 30 years or until the remedial action goals are achieved, whichever comes first. Where restoration timeframes will extend considerably beyond the 30 year period an alternative O&M period will be considered to more accurately represent the probable cost of the remedial alternative. The discount rate that will be used for calculating present worth will be the 5%.

The development and screening of alternatives will be performed throughout the RI/FS in a phase manner that will include the:

- identification of ARARs;
- identification of remedial action objectives;
- development of general response actions;
- evaluation of the volumes or areas of media to which the general response actions might be applied;
- identification and screening of remedial technologies and process options;

- assembly of remedial alternatives;
- refinement of remedial alternatives; and
- screening of remedial alternatives.

Identification of Applicable or Relevant and Appropriate Requirements

ARARs are developed to serve as a basis for establishing general response actions for various site media. The preliminary list of ARARs presented in Section 3.0 of this Work Plan will be updated throughout the RI/FS as new information is generated. The evaluation of ARARs will include, to the degree appropriate, AOC-specific considerations relative to current and future use and COPCs.

The NCP and SARA require that primary consideration be given to remedial alternatives that attain or exceed ARARs. ARARs will be used as the primary basis for remedial action objectives and as an evaluation criteria in the detailed analysis of alternatives (Task IXA). Section 121 of SARA requires that the remedy for a CERCLA site must attain all ARARs unless one of the following conditions is satisfied:

1. the remedial action is an interim measure where the final remedy will attain the ARAR upon completion;
2. compliance will result in greater risk to human health and the environment than other options;
3. compliance is technically impracticable;
4. an alternative remedial action will attain the equivalent of the ARAR;
5. for state requirements, the state has not consistently applied the requirement in similar circumstances; or

6. compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the facility with the Fund money for response at other facilities (Fund-balancing).

In the event that one of the foregoing conditions is met, the USEPA can make a determination for an ARAR waiver. ARAR waivers would be described in the ROD. If an ARAR waiver is appropriate for the BROS site, the RI/FS information would provide the administrative and technical support for the ARAR waiver.

Identification of Remedial Action Objectives

Remedial action objectives will be updated, throughout the RI/FS, for each AOC identified during the human health or ecological risk assessment as posing potentially significant risk to receptors. Remedial action objectives consist of medium-specific or AOC-specific goals that are protective of human health and the environment. Remedial action objectives specify:

- constituents of potential concern;
- exposure routes and receptors; and
- an acceptable contaminant level or range of levels for each exposure route.

Final acceptable exposure levels will be determined on the basis of the results of the human health and ecological risk assessments and available ARARs.

Development of General Response Actions

General response actions are the types of remedial actions, such as containment, institutional controls, extraction or excavation, that are taken to satisfy the remedial action objectives. General response actions are medium specific. General response actions will be refined from the preliminary actions outlined in Section 4.0 over the course of the RI/FS. To the degree appropriate based upon the patterns of data and the risk assessments, general response actions will be developed for each medium of interest at specific AOCs or hot spots in order to facilitate the evaluation of risk-based remedies.

Evaluation of the Volumes or Areas of Media

Based upon the RI data, an estimate of the volumes of media requiring remedial actions will be developed. The volumes will be estimated within the context of the remedial action objectives. Initially, these evaluations will be made on a medium-specific basis within each AOC. Where the grouping of AOCs and/or media is warranted, overall volume estimates will be developed.

Identification and Screening of Remedial Technologies and Process Options

The identification and screening of remedial technologies and process options involves the reevaluation of remedial technologies previously identified and screened in Section 4.0, based upon the results of the RI and the prior FS tasks conducted to date. The universe of remedial technologies will be reevaluated to ensure completeness and to reassess any innovative or emerging technologies. The technology screening will be updated to consider relevant AOCs, based upon RI data and the risk assessment input. For each AOC, specific process options that are most directly applicable to the technical (e.g. site characteristics, engineering limitations) and regulatory requirements (e.g. remedial action objectives) will be selected to choose one process for each remedial technology prior to the screening process. Following the selection of process options, a screening will be conducted, similar to that outlined in Section 4.0. The screening of remedial technologies and process options will be completed for each AOC on the basis of effectiveness, implementability and cost. To ensure USEPA input to the screening of remedial technologies and process options, the results of this screening will be discussed with USEPA at one of the monthly meetings.

Assembly of Remedial Alternatives

Remedial alternatives will be formulated, in a manner similar to that outlined in Section 4.4, for each AOC by combining remedial technologies that pass the screening process with other necessary process options or considerations. The remedial alternatives identified will achieve the established remedial action objectives. At the BROS site, the interactions between various media are significant, and will likely warrant the integration of remedial technologies for various media at each AOC. Together, all of the remedial alternatives will represent a range of combinations that will address the remedial action objectives for the site.

Refinement of Remedial Alternatives

The remedial alternatives will be refined to identify the volume of contaminants addressed by the remedial processes. This information will be used for subsequent comparisons of the degree that the alternatives reduce the volume of wastes through treatment and for the sizing of critical unit operations in relationship to effectiveness, implementability, and cost.

The remedial alternatives will be refined based upon the updated PRGs (Task VIA, Activity 1b) and the updated ARARs.

6.8.2 Task VIIIB - Conduct and Document Screening Evaluation of Each Alternative

A remedial alternatives screening step will be conducted to reduce the number of potential alternatives considered for detailed analysis. Screening will not be necessary for AOCs where only a few options emerged from the development of alternatives phase. Alternative screening will be performed to evaluate relative short and long term effectiveness, implementability, and relative cost of candidate alternatives. The screening will be conducted to assure that only the alternatives with the most favorable composite evaluation of all factors are retained for further analysis. The range of remaining alternatives will include options that meet the NCP objectives of use of treatment and use of permanent remedies, will providing a range of degree of treatment and restoration times.

The screening of remedial alternatives will take into account those site-related factors that limit or prevent the attainment of the remedial action objectives, and will influence the restoration timeframes. Examples of those factors with potential applicability to the BROS site, include restoration of ground water containing NAPL and the presence of low permeability materials with a high affinity for site-related COPCs. These topics are discussed in more detail below to provide stakeholders with an understanding of how similar issues will be addressed in the FS.

The presence of LNAPL within the lagoon residuals has been reported by USEPA. As outlined in Section 4.0 and Appendix A, the practicability of restoring ground water in and downgradient of NAPL areas to ARARs must be evaluated for the BROS site. The lagoon residuals may be

predominantly associated with the peat layer underlying the former lagoon. The peat layer extends under and beyond the confines of the former lagoon. The relative thickness is known to be variable but the actual thickness is not known. The surrounding stratigraphic units have differing permeabilities and transmissivities and may also contain COPCs. These units include fill material surrounding the former lagoon, backfill, and the silt and clay layer between the Upper PRM and Upper Middle PRM aquifers.

The spatial distribution of the peat layer, coupled with its high organic content, will impede diffusion and advection of contaminants - but will also limit the effectiveness of extraction technologies. As such, pump-and-treat technologies will be ineffective; a problem compounded by the likelihood of preferential flow paths through adjacent higher permeability strata and likely slow the diffusion from the underlying silt/clay layer.

Similar concerns for the removal of sources exist for NAPL on the water table and below the water table in several areas throughout the BROS property. The analysis of technical feasibility of ground water remedies and the definition of remedial action objectives will involve the use of current guidance and published literature including:

- *Pump-and-Treat Ground-Water Remediation; A Guide for Decision Makers and Practitioners* (USEPA, 1996g);
- the NCP;
- the Presumptive Remedy Guidance; and
- *EPA Guidance on Evaluating the Technical Impracticability of Ground Water Restoration* (USEPA, 1993a)

The remedial alternatives screening will employ a decision matrix similar to Table 1 (Categories of Sites for Technical Infeasibility Determinations) in Pump-and-Treat Ground-Water Remediation

(USEPA, 1996g) which provides an outline of chemical and hydrologic conditions relative to the feasibility of achieving health-based standards.

For those AOCs where attainment of health-based standards is not practical, or will not be achievable within a reasonable timeframe, alternative approaches consistent with the NCP will be retained. These may include proposals for USEPA to apply ARAR waivers, ACLs or use restrictions. Further, a Classification Exception Area (CEA) will be established for areas where ground water quality does not, or will not, meet the New Jersey GWQC (NJDEP, 1995). ACLs, CEAs and use restrictions were discussed in Section 4.1.

To address the issue of pump-and-treat practicability, the USEPA issued guidance on evaluating the technical impracticability of ground water restoration in 1993 (USEPA, 1993d). This guidance was prepared to address the issue of how to determine whether ground water cleanup goals are technically achievable at a particular site, and how to establish an alternative, protective cleanup strategy where restoration is determined to be technically impracticable. This guidance document states that "this guidance does not signal a scaling back of EPA's efforts to restore contaminated ground waters at Superfund sites and RCRA facilities. Rather, EPA is promoting the careful and realistic assessment of the technical capabilities at hand to manage risk posed by ground water contamination. This guidance provides consistent guidelines for reevaluating technical impracticability and for maintaining protectiveness at sites where ground water cannot be restored within a reasonable time frame."

TI Determinations include the following components, as specified *EPA Guidance on Evaluating the Technical Impracticability of Ground Water Restoration* (USEPA, 1993a):

1. identification of specific ARARs or media-specific cleanup standards for which a TI waiver is being sought;

2. identification of the spatial area over which the TI Determination will apply (i.e., the TI zone);

3. a conceptual model that describes site geology, hydrogeology, ground water contamination sources, transport and fate;

4. evaluation of the restoration potential of the site, including;

   - a demonstration that contamination sources have been identified and have been, or will be, removed and contained to the extent practicable;

   - an analysis of the performance of any ongoing or completed remedial actions;

   - predictive analysis of the time frames to attain required cleanup levels using available technologies;

5. demonstration that no other remedial technologies (conventional or innovative) could attain cleanup levels within a reasonable time frame;

6. estimates of the costs of existing or proposed remedy options; and

7. any additional information that is deemed relevant for the Determination.

Based upon the current understanding of site conditions, components 2 through 4 are inherently dependent upon the site-specific factors presented in the conceptual model and will be more fully evaluated within the context of the data collected during the Phase 2 RI.

6.8.3 Task VIIIC- Presentation of Remedial Action Objectives and Development and Screening of Alternatives

Following the refinement and screening of remedial alternatives, the results of Task VIII will be presented to the USEPA and NJDEP in a meeting. The presentation will include:

- an overview of the ARARs, TBCs and PRGs for each AOC and for the site as a whole;

- an identification of remedial action objectives;

- a summary of the candidate technology types, process options and remedial alternatives;
- a description of the results and reasoning employed in the remedial alternatives screening; and
- a summary of the remedial alternatives that remain for each AOC after the screening.

Based upon the comments received during the presentation, a Technical Memorandum will be prepared to summarize the presentation and respond to agency comments.

6.9 Task IX- Feasibility Study Report

The FS will be performed for the BROS site in an iterative fashion based on the findings of the field investigations and the risk assessment as they are updated. The FS will be conducted in accordance with the Consent Decree; CERCLA, as amended by SARA; the National Contingency Plan; RAGS Part D (USEPA, 1998f) and USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. The FS will entail the following work efforts.

6.9.1 Task IXA - Detailed Analysis of Alternatives

A detailed analysis of remedial alternatives will be conducted for each media within any AOC where a significant risk exists based on the baseline risk assessment. The development and evaluation of alternatives will take into account the COPCs and exposure routes that present significant risks identified during the baseline risk assessment. This analysis will be conducted in accordance with the nine evaluation criteria set forth in the NCP. The analysis is dependent on the availability of sufficient cost and performance data to evaluate technologies and the degree to which the alternatives have been previously analyzed during their development and screening. A thorough analysis is necessary to identify implementable remedies including an assessment of relative performance evaluation between the alternatives. The nine evaluation criteria are:

1. Overall protection of human health and the environment;
2. Compliance with ARARs;

3. Long-term effectiveness and permanence;
4. Reduction of toxicity, mobility, and volume through treatment;
5. Short-term effectiveness;
6. Implementability;
7. Cost;
8. State Acceptance; and
9. Community Acceptance.

Information about State and community acceptance of remedial alternatives is incorporated in the ROD, after the NJDEP and the public have had an opportunity to review the draft RI/FS report and participate in a public meeting. As outlined in the Community Relations Participation Proposal (Roux, 1997); fact sheets, progress reports and an information repository are being distributed and made available to the public. Moreover, the routine interaction with residents surrounding the former BROS property as part of the access agreement process will provide additional information on community concerns, expectations and sensitivities.

The remedial alternatives will be refined or further defined based upon the RI data and treatability study results. Consideration will be given to the volumes and areas of materials requiring management, and to the results of pilot tests and treatability studies that provide sizing or efficacy data. If additional conceptual design is required to provide for the consistent application of evaluation criteria or to develop order-of-magnitude cost estimates, the alternatives will be more fully defined. This may include the preparation of preliminary design layouts, initial design calculations and/or further assessment of critical assumptions and uncertainties.

Initially, each alternative will be presented individually and analyzed with respect to the nine criteria listed above. Narrative descriptions of each alternative will be prepared, along with a discussion of the criteria assessment. Data pertaining to technology components, quantities of material handled, time required for implementation, implementation requirements, uncertainties, and critical assumptions will be developed and summarized. Alternative-specific consideration of ARARs will also be performed.

Once each alternative is individually presented and evaluated in detail, a comparative analysis of the alternatives will be performed to assess the relative performance of each in relation to the evaluation criteria. The advantages and disadvantages of each alternative, relative to one another, will be considered. In the comparative evaluation process, overall protection of human health and the environment and compliance with ARARs will be generally serve as the primary factors in selecting a preferred remedy.

6.9.2 Task IXB - Detailed Analysis Deliverables

Activity 1a - Draft FS Report

A draft FS Report will be prepared for the BROS Phase 2 RI/FS. The FS Report will provide the basis for remedy selection and will address each AOC. The draft FS Report includes the following:

1. An executive summary.
2. An introduction summarizing information from the RI report.
3. A description of the technology identification, evaluation, and screening process.
4. A description of the development and screening of alternatives.
5. Detailed analysis of alternatives against the nine evaluation criteria.
6. Comparative analysis of alternatives.

Technology and alternative screening and evaluation process details will be presented both in text and tabular format. Narrative discussions and summary tables will be employed to facilitate the effective communication of the analysis process. Backup information and calculations will be included as appendices where this information will facilitate the understanding and evaluation of the FS Report. As with the Work Plan, a list of acronyms and a bibliography of references will be included in the FS Report. Appendices will include:

- documentation from the presentation of RAOs and the development and screening of alternatives (Section 6.8.3);
- summaries of the conceptual design used in the development and screening of alternatives;

- supporting documentation from the cost analysis; and

- descriptions and documentation of existing land use restrictions.

The draft FS Report will be provided to the USEPA and NJDEP for review and comment.

Activity 1b - Final FS Report

Based upon agency comments, the FS Report will be revised, if necessary, and the final version will be resubmitted. The Community Relations Participation Proposal (Roux, 1997) details the scope of the BROS Technical Committee's support to USEPA and NJDEP during the public meeting and responsiveness summary process following submission of the final FS Report.

7.0 COSTS AND KEY ASSUMPTIONS

Several comments received during the second scoping meeting and as part of the EPA's review of the Draft Phase 2 RI/FS Work Plan will substantially increase the costs of the Phase 2 RI activities depending upon the extent they are implemented. Important cost-related concerns are listed below.

- Attempting completion of the ecological investigations and surface water/sediment sampling in a single investigative phase, as opposed to employing an iterative approach, would result in the collection and analysis of a large number of samples -with attendant costs for analysis, data management, data evaluation and reporting. This approach will not yield the information needed for decision making, largely because samples would be misplaced. The phased approach will provide cost-control through the direction of subsequent sampling efforts based upon concentration gradients from earlier phases and the opportunity to refine the analytical suite based upon a review of initial data, the PRGs and input from the EPA. In addition, a phased approach will reduce uncertainties and decrease remedial costs.

- The DQOs outlined in the QAPP are based upon an assessment of site-related COPCs and the initial PRGs. The DQOs reflect the matrix complexities and limitations particular to the site, in accordance with the approved Statement of Work (Consent Decree, Appendix E). In the event that special laboratory cleanup methods are required, or more stringent DQOs are established, laboratory costs will increase.

- The selection of COPCs and indicator parameters was kept relatively comprehensive for the initial phases of the RI. The analytical suite for subsequent phases will be updated based upon a comparison of new data and the iterative risk assessment, feasibility study and modeling efforts. In the event that the USEPA requires that a broad analytical suite be retained or only minimally reduced; laboratory, data management and reporting costs will increase.

- The ground water investigations have been developed, based upon the existing data, to establish the distribution of COPCs using gradients apparent in the early 1990's. The proposed ground water investigation includes a combination of investigative methods that that along and perpendicular to the axis of ground water movement from source areas, including monitoring wells screened at multiple depth intervals. Moreover, the plan includes the use of slotted augers in the area south of I-295, within the limitations outlined in Section 6.3, to select the screened interval for monitoring wells in this area and provisions for an iterative ground water study that will include additional monitoring wells if needed based upon the initial phases of the investigation. The USEPA has proposed the use of slotted augers throughout a large portion of the Little Timber Creek Swamp and throughout the agricultural properties south of I-295. The use of slotted augers to assess multiple sampling locations and depths would be costly and present difficulties due to access limitations, the need for road-building efforts and the costs of data collection, management and reporting.

- The evaluation of COPC fate and transport via surface water will be conducted using empirical data. The data collection requirements to apply a computer-based surface water model in the diffuse wetlands of Little Timber Creek Swamp would be costly due to the complexity of the wetland flow patterns and the seasonal variability. The costs of completing the type of hydrologic and geochemical study necessary to support a computer-based surface water model would be substantial and are unlikely to significantly reduce the uncertainty as compared to the proposed analysis of empirical data.

- The collection of water level and flow data to complete the water budget analysis is costly due to the difficulties associated with working in the wetlands and the relatively modest topographic relief across the study area. More frequent data collection would provide little additional information about the study period, and will not significantly reduce uncertainty for decision making purposes because the water budget analysis will still require extrapolation based upon long-term climatic and hydrologic data.

- Although DNAPL is not predicted based upon an analysis of the existing data, a DNAPL investigation will be conducted to confirm the absence of DNAPL. Studies for DNAPL have been added that include the estimation of solubilities for tentatively identified compounds and field screening methods such as hydrophobic dye tests and UV fluorescence. These studies will result in increased RI/FS costs to further evaluate the potential for DNAPL.

8.0 SCHEDULE

A detailed schedule for the Phase 2 RI/FS has been prepared consistent with the EPA-approved schedule (Plate 1). The schedule identifies the various RI/FS tasks presented in this Work Plan, along with the schedule interdependencies between tasks and subtasks. The overall project schedule is predicated on USEPA's April 2, 1999 approval of the Phase 2 RI/FS Work Plan, QAPP, SAP and HASP). The completion of the work activities detailed in this Work Plan in accordance with the schedule may be influenced by the findings of the investigations and site conditions during the field activities. For example, weather conditions and seasonal hydrologic variations such as premature drying out of the swamp may postpone the sampling of surface water in Little Timber Creek Swamp. The project schedule (Plate 1) has been established, to the degree practical, to minimize the probability of unforeseen delays.

The overall schedule is driven by the season sensitive aquifer pumping tests and ecological risk assessment field data collection efforts. Specifically, the aquifer tests will be performed during the driest period of the year, late summer, to provide a realistic and empirical basis for predicting the influence of ground water extraction on the wetlands. Information from the CLTL extraction system and available regional hydrology data can then be used to for the conceptual design of a pumping system that will be effective during wetter periods. This information will be used for the evaluation of remedial alternatives.

The ERA data collection must be conducted during two periods representing both wet and dry conditions in the wetland areas. As such, data collection will be completed in two phases, one between April and June, and the other between August and early October. In addition to providing both wet and dry season data, these periods correspond to the time when canopy cover is established, juvenile amphibians have matured to identifiable life stages, winter migrants have returned and the maximum numbers of aquatic macroinvertebrates are present.

An advantage of the planned schedule is that it provides an opportunity for subsequent phases of the RI delineation efforts, if necessary. This opportunity is a function of the period of time between the likely Work Plan approval and the aquifer tests and ERA data collection.

9.0 PROJECT ORGANIZATION

The overall management structure for completing the Phase 2 RI/FS (Figure 31) and a general summary of the responsibilities of the key individuals involved with implementation and completion of the project are presented below.

9.1 BROS Technical Committee

The BROS Technical Committee is composed of representatives of the Settling Defendants who are senior managers and are responsible for the implementation of the Phase 2 RI/FS and subsequent remedial design and remedial actions, as per the Consent Decree (USDA, 1997a). The BROS Technical Committee is responsible for making strategic decisions and monitoring the overall project progress.

9.2 Project Coordinator for the Settling Defendants

The Project Coordinator serves as a representative of the BROS Technical Committee and manages the contractor completing the Phase 2 RI/FS. It is the Project Coordinator's responsibility to serve as a liaison between the BROS Technical Committee, the contractor completing the Phase 2 RI/FS and the USEPA's Project Manager. Peter Brussock, Ph.D. of Environmental Liability Management, Inc. serves as the Project Coordinator for the Settling Defendants.

9.3 Project Principal

The Project Principal, a principal with the RI/FS contractor, is responsible for defining project objectives, allocating resources, determining chain-of-command, and evaluating program outcome. The Project Principal is ultimately responsible for overall site activities. Douglas Swanson of Roux Associates, Inc. is the Project Principal for the Phase 2 RI/FS.

9.4 Project Manager

The Project Manager is responsible for all day-to-day activities of the RI/FS contractor. He obtains permission for site access, delegates work assignments, coordinates activities with

appropriate officials, manages the subcontractors performing tasks, and tracks the project costs, budget and schedule of the Phase 2 RI/FS. The Project Manager is Neil Rivers of Roux Associates, Inc.

9.5 RI Manager

The RI Manager is responsible for day-to-day activities associates with the implementation of the RI activities. The RI Manager coordinates the completion of field activities and preparation of deliverables. The RI Manager is William Gilchrist of Roux Associates, Inc.

9.6 Ecological Risk Assessment Manager

The Ecological Risk Assessment Manager is responsible for the study design, investigation and evaluation activities associated with the ecological risk assessment (ERA). The Ecological Risk Assessment Manager directs all field team personnel and oversees the data analysis and risk characterization activities. Dr. Swiataslov Kaczmar of O'Brien and Gere Engineers, Inc. will serve as Ecological Risk Assessment Manager.

9.7 Human Health Risk Assessment Manager

In addition to the individuals introduced above, the Human Health Risk Manager and technical support for the implementation of the Phase 2 RI/FS will include:

- Dr. Simon Lock, Roux Associates, Inc., will coordinate the human health risk assessment;
- James Rumbaugh, Environment Simulations, Inc. will assist with the surface water/ground water modeling to support the risk assessment and FS; and
- Michael Marley, Envirogen, Inc., will provide technical support with the evaluation of natural attenuation to support the risk assessment and FS.

9.8 Feasibility Study Manager

Mr. Patrick J. Hansen, P.E. of Roux Associates, Inc. will manage the Feasibility Study activities. Mr. Hansen will oversee the detailed analysis of remedial alternatives based on data collected

from the site, the comparison of potential remedial alternatives against each other, and the preparation of the Feasibility Study Report.

9.9 Data Validation

Data validation will be accomplished by Ms. Judy Harry of Data Validation Services at Roux Associates, Inc.'s direction. Ms. Harry will conduct a systematic review of the data for compliance with the established QC criteria. The data validator will also evaluate the accuracy, precision, representativeness, completeness and usability of the data.

9.10 Field Team Leader

Mr. John Lucey, P.G., of Roux Associates, Inc. will be the Field Team Leader. The Field Team Leader bears the responsibility for the successful execution of the field program. The Field Team Leader directs the activities of technical staff in the field and assists in the interpretation of physical and chemical data, and report preparation. Responsibilities include the management of technical staff, and oversight of subcontractors such as the driller and laboratory.

9.11 Site Health and Safety Officer

Ms. Brigid Tigani of Roux Associates, Inc. will be the Site Health and Safety Officer (SHSO) Ms. Tigani is responsible for health and safety activities throughout the Phase 2 RI/FS. The SHSO is responsible for implementation of the Health and Safety Plan.

9.12 Laboratory Manager

Two off-site analytical laboratories and one on-site analytical laboratory will provide analytical services for the Phase 2 RI/FS. The use of three laboratories is intended to provide rapid on-site screening and to ensure capacity and technical expertise for the complex matrices known at the BROS site. The project manager for the primary off-site analytical laboratory, Lancaster Laboratories, Inc., is Ms. Missy McDermott. The secondary off-site laboratory will be determined during the first six months of the RI activities, after the rate of sample production is more accurately established. The project manager for the on-site laboratory, On-Site Environmental Laboratories, Inc., is Mr. Lonnie Fallin. Each manager is responsible for sample

container preparation, sample custody in the laboratory, and completion of the required analysis through oversight of their laboratory staff. The Laboratory Manager will ensure that quality assurance procedures are followed and that an acceptable laboratory report is prepared and submitted. To provide additional support to technical and methodology questions during on-site analytical services, the on-site laboratory will team with the primary laboratory throughout the project.

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TABLES

Table 1. Summary of Existing Monitoring Well Construction Information. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Well	Date Installed	Diameter (in)	Borehole Depth (ft BGS)	Screen Setting (ft BGS)	Initial Depth to Water Level from TOC (ft BGS)	TOC Elevation (ft ASL)	Aquifer Monitored
MW-1A	1990	2	23	2-12	6.33	10.84	Surficial/Upper PRM
MW-1C	Aug-90	2	181	132-142	6.82	9.41	Lower Middle PRM
MW-2C	Sep-90	2	138	127-137	4.62	7.24	Lower Middle PRM
MW-3A	1990	2	14	4-14	9.85	13.34	Surficial/Upper PRM
MW-3C	Jul-90	2	145	125-135	7.94	10.67	Lower Middle PRM
MW-4A	1990	2	13	2-12	7.19	11.12	Surficial/Upper PRM
MW-4C	Aug-90	2	180	168-178	8.65	10.56	Lower Middle PRM
MW-5B	Aug-90	2	135	100-110	13.50	16.63	Upper Middle PRM
MW-6A	1990	2	15	5-15	8.91	12.31	Surficial/Upper PRM
MW-6B	Aug-90	2	110	90-100	9.18	12.37	Upper Middle PRM
MW-7A	1990	2	15	5-15	6.62	10.04	Surficial/Upper PRM
MW-7B	Aug-90	2	85	62-72	6.97	10.16	Upper Middle PRM
MW-8A	1990	2	17	7-17	8.29	11.54	Surficial/Upper PRM
MW-8B	Aug-90	2	103	92-102	8.92	11.94	Upper Middle PRM
MW-9A	1990	2	16	5-15	7.06	11.14	Surficial/Upper PRM
MW-9B	Aug-90	2	100	85-95	8.22	11.23	Upper Middle PRM
MW-10A	1990	2	16	5-15	9.63	12.97	Surficial/Upper PRM
MW-10B	Sep-90	2	135	120-130	10.95	12.78	Upper Middle PRM
MW-11A	1990	2	15	4-14	6.89	10.73	Surficial/Upper PRM
MW-11A(D)	1990	2	75	65-75	5.82	9.63	Base of Upper PRM
MW-11B	Aug-90	2	145	132-142	9.57	11.82	Upper Middle PRM
MW-12A	Aug-90	2	14	4-14	5.15	8.71	Surficial/Upper PRM
MW-12B	1990	2	162	133-143	7.16	10.95	Upper Middle PRM
MW-13A	Aug-90	2	16	5-15	5.37	8.74	Surficial/Upper PRM
MW-14A	1990	2	115	105-115	18.68	16.68	Base of Upper PRM
MW-14B	1990	2	203	190-200	19.94	16.7	Upper Middle PRM
MW-15A	1990	2	118	105-115	14.84	12.79	Base of Upper PRM
MW-15B	1990	2	196	186-196	16.54	12.86	Upper Middle PRM
MW-16A	1990	2	130	120-130	13.30	9.66	Base of Upper PRM
MW-16B	1990	2	192	182-192	13.58	9.69	Upper Middle PRM
S-1A	1983/1984	4	23	13-23	5.09	8.01	Upper PRM
S-1B	1983/1984	4	30	20-30	5.24	7.82	Base of Upper PRM
S-1C	1983/1984	4	57	20-30	5.47	8.07	Upper Middle PRM
S-2A	1983/1984	4	15	5-15	8.14	--	Surficial/Upper PRM
S-2B	1983/1984	4	50	40-50	10.55	12.62	Upper Middle PRM (Top)
S-2C	1983/1984	4	116	98-108	11.38	13.41	Base of Upper Middle PRM

Table 1. Summary of Existing Monitoring Well Construction Information. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Well	Date Installed	Diameter (in)	Borehole Depth (ft BGS)	Screen Setting (ft BGS)	Initial Depth to Water Level from TOC (ft BGS)	TOC Elevation (ft ASL)	Aquifer Monitored
S-3A	1983/1984	4	15	5-15	7.50	10.16	Surficial/Upper PRM
S-3B	1983/1984	4	55	40-50	6.88	10.34	--
S-3C	1983/1984	4	102	90-100	7.95	10.75	Base of Upper Middle PRM
S-4	1983/1984	4	19	9-19	12.60	15.5	Surficial/Upper PRM
S-5	1983/1984	4	72	60-70	4.93	7.41	Upper Middle PRM
S-6	1983/1984	4	92	79-89	7.68	8.87	Base of Upper Middle PRM
S-8	1983/1984	4	85	75-85	8.73	10.81	Upper Middle PRM
S-9	1983/1984	4	52	40-50	4.95	7.58	Upper PRM
S-11A	1983/1984	4	15	5-15	3.96	8.86	Surficial/Upper Middle PRM
S-11B	1983/1984	4	95	81-91	7.29	9.22	Upper Middle PRM
S-11C	1983/1984	4	157	105-115	7.65	9.19	Base of Upper Middle PRM
EPA-101	Jun-81	2	46	35-37	4.66	7.56	Base of Upper Middle PRM
EPA-102	Jun-81	2	51	36-38	11.58	14.38	--
EPA-103	Jun-81	2	55	45-47	8.86	11.06	Upper PRM
EPA-104S	Jun-81	2	102	19-21	6.72	9.21	Upper PRM
EPA-104D	Jun-81	2	102	49-51	6.96	--	Upper Middle PRM
EPA-105	Jun-81	2	51	40-42	7.56	9.76	--
EPA-106	Jun-81	--	52	40-42	--	8.07	--
EPA-107	Jun-81	2	51	36-38	6.21	8.23	Upper Middle PRM
EPA-108	Jun-81	2	100	86-96	6.37	8.48	Upper Middle PRM
NJDEP	Oct-81	--	100	84-97	--	--	Upper Middle PRM
P-1	Dec-89	4	19	14-19	10.08	--	Surficial/Upper PRM
P-2	Dec-89	4	20	15-20	8.25	--	Surficial/Upper PRM
P-3	Dec-89	4	20	15-20	10.00	--	Surficial/Upper PRM
P-4	Jan-90	4	19	14-19	8.00	--	Surficial/Upper PRM
P-5	Dec-90	4	19	14-19	14.00	--	Surficial/Upper PRM

Notes:

Ft. BGS = Feet Below Ground Surface
TOC = Top of Casing
Ft. ASL = Feet Above Sea Level
PRM = Potomac-Raritan-Magothy Aquifer System
IN = Inches

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Table 2a. Surface Water and Sediment Sample Results for Little Timber Creek. June 1990. BROS Phase 2 RI/FS, Bridgeport, New Jersey.

Surface Water (μg/ℓ)	NJDEP SWQC[1]	DRBC SQO[2]	LTC-01	LTC-02	LTC-03	LTC-04	LTC-05
Benzene	0.15	12.5[4]	4J	0.5U	0.5U	0.5U	0.5U
Arsenic	0.017	36	2U	3.4	2U	2U	2.3
Lead	5	8.5	19.7R	76.9	11.6R	1.7R	3.5R
Manganese	100	--	24.7	282	119	289	208
Selenium	10	71	3U	3U	3U	3U	4.6J
PCBs (Aroclor-1260)	0.014[5]	0.03[5]	2	1U	10U	1U	1U
Sediments (mg/kg)	**Ontario LEL[3]**						
Arsenic	6		4.4	2.7	7.3J	0.68	0.53U
Cadmium	0.6		5J	1.3U	2U	1U	1.1U
Copper	16		13.3	4.7	17.5J	2.3	0.53U
Chromium	26		71.9	15.5	35.1J	7.1	5.7
Lead	31		252	141	666J	8.7	16.9
Zinc	120		195	41.1	152J	18.9J	22.9
PCBs (Aroclor-1260)	5		2J	0.27J	1.7J	0.38U	0.41U
PAHs (Total)			11.61J	3.51J	ND	ND	ND
Benzo(a)anthracene	0.32		0.93J	0.21J	1.4U	0.4U	0.84U
Benzo(a)pyrene	0.37		1.5J	0.16J	1.4U	0.4U	0.84U
Benzo(g,h,i)perylene	0.17		0.56J	0.95	1.4U	0.4U	0.84U
Chrysene	0.34		1.1	0.22	1.4U	0.4U	0.84U
Indeno(1,2,3cd)pyrene	0.2		0.45J	0.95	1.4U	0.4U	0.84U
Phenanthrene	0.56		0.16J	0.78J	1.4U	0.4U	0.84U
Pyrene	0.49		3.8J	0.65J	0.34U	0.4U	0.84U

Samples collected June 1990 by CH_2M/Hill as presented in March 1996, Summary of Phase Two Remedial Investigation Performed to Date.

Results listed for those constituents of potential ecological concern that were detected.

U = Not detected at the identified detection limit.

R = Data was qualified as unusable.

J = Estimated value.

(1) New Jersey Surface Water Quality Criteria (SWQC) for FW2 waters at N.J.A.C. 7:9B-1.14.

(2) Delaware River Basin Commission (DRBC) Stream Quality Objectives (SQO) for Toxic Pollutants for the Protection of Aquatic Life in the Delaware River Estuary (Marine Objectives) unless otherwise note

(3) Lowest Effects Level (LEL) from Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario, August 1993.

(4) DRBC stream quality objectives for carcinogens in the Delaware River Estuary (Marine Objectives).

(5) Total PCBs.

Table 2b. Surface Water and Sediment Sample Results for Gaventa Pond. June 1990. BROS Phase 2 RI/FS, Bridgeport, New Jersey.

Surface Water (µg/ℓ)	NJDEP SWQC[1]	DRBC SQO[2]	GVP-01	GVP-02	GVP-03
Antimony	12.2	--	26U	26U	378
Copper	--	3.4	6.8	2U	2U
Lead	5	8.5	314	2.5R	1.8R
PCBs (Aroclor-1260)	0.014[4]	0.03[4]	135J	1U	1U

Sediments (mg/kg)	Ontario LEL[3]	GVP-01	GVP-02	GVP-03
Arsenic	6	1.5	17.3J	2
Chromium	26	6.4	39.2J	9.3
Copper	16	3.1	17.4J	0.48U
Lead	31	28.1	42.5J	2.1R
PCBs (Aroclor-1260)	5	2.2J	1.1U	1.1U

Samples collected June 1990 by CH_2M/Hill as presented in March 1996, Summary of Phase Two Remedial Investigation Performed to Date.
Results listed for those constituents of potential ecological concern that were detected.
U = Not detected at the identified detection limit.
R = Data was qualified as unusable.
J = Estimated value.
(1) New Jersey Surface Water Quality Criteria (SWQC) for FW2 waters at N.J.A.C. 7:9B-1.14.
(2) Delaware River Basin Commission (DRBC) Stream Quality Objectives (SQO) for Toxic Pollutants for the Protection of Aquatic Life in the Delaware River Estuary (Marine Objectives) unless otherwise noted.
(3) Lowest Effects Level (LEL) from Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario, August 1993.
(4) Total PCBs.

Table 2c. Sediment Sample Results for Swindell Pond, June 1990. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	Ontario [1] LEL	SDP-01	SDP-01(D)	SDP-02	Average from Swindell Pond
Arsenic	6	0.66	0.99	17.4J	6
Chromium	26	3.5	5.3	38.3J	16
Copper	16	0.48U	0.5U	22.9J	8
Lead	31	3.6R	4.7	55J	21
Zinc	120	5J	6.8J	130J	47

Samples collected June 1990 by CH_2M/Hill as presented in March 1996, *Summary of Phase Two Remedial Investigation Performed to Date.*
All results in mg/kg.
Results listed for those constituents of potential ecological concern that were detected.

U = Not detected at the identified detection limit.
R = Data was qualified as unusable.
J = Estimated value.
[1] Lowest effect level from *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario*. Persaud, D. et al, 1993.

Table 3. Preliminary Identification of Chemical-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
I. CHEMICAL-SPECIFIC Soil Federal Requirements • Soil Screening Levels (SSLs) (4/96)		X
• 40 CFR 260 *et al.*, Requirements for Management of Hazardous Contaminated Media - Proposed Rule (61 FR 18780, 4/29/96)		X
• Guidance on Remedial Actions for Superfund Sites with PCB Contamination (EPA 540 G-90-007)		X
• 40 CFR 761.120-135, PCB Spill Cleanup Policy		X
• 40 CFR 761, Disposal of Polychlorinated Biphenyls-Proposed Rule (59 FR 62788, 12/6/94)		X
2. State Requirements • Soil Cleanup Criteria		X
B. Incineration Residuals 1. Federal Requirements • 40 CFR 260.22, Delisting Petitions	X	
2. State Requirements • N.J.A.C. 7:26-8.17, Delisting Procedure	X	
C. Debris 1. Federal Requirements • 40 CFR 268.45, Hazardous Debris	X	
2. State Requirements • N.J.A.C. 7:26-8.4 Residues of Hazardous Waste in Empty Containers	X	
D. Sediment 1. State Requirements • Guidance for Sediment Quality Evaluations (3/91)		X
• Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (8/93)		X

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Table 3. Preliminary Identification of Chemical-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
A. Surface Water		
1. Federal Requirements		
• 40 CFR 131, Water Quality Standards	X	
• Ambient Water Quality Criteria	X	
2. State Requirements		
• N.J.A.C. 7:9B-1.14, Surface Water Quality Criteria	X	
• N.J.A.C. 7:9B-1.14 (28 N.J.R. 372-376), Proposed Surface Water Quality Criteria		X
B. Ground Water		
1. Federal Requirements		
• Safe Drinking Water Act 40 CFR 141 and 143	X	
2. State Requirements		
• Safe Drinking Water Act, New Jersey MCLs N.J.A.C. 7:10	X	
• N.J.A.C. 7:9-6, Table 1, Ground Water Quality Standards	X	
• Revised Table of Interim Specific Criteria, NJ Ground Water Quality Standards, N.J.A.C. 7:9-6 (April 15, 1996)		X

Table 4. Preliminary Identification of Location-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
LOCATION-SPECIFIC Floodplain Management Federal Requirements		
• 40 CFR 6.302 with Appendix A and Executive Order 11988: Protection of Floodplains, NEPA Procedures	X	
• OSWER Directive 9280.0-0: Policy on Floodplain Assessments for CERCLA Actions		X
• 40 CFR 264.18(b): RCRA TSD Location Standards	X	
2. State Requirements • N.J.S.A. 23:2A-1 *et seq.*, Flood Hazard Control Act	X	
B. Wetlands Protection 1. Federal Requirements • 40 CFR 6.302(a) with Appendix A and Executive Order 11988: Wetlands Protection, NEPA Procedures	X	
• OSWER Directive 9280.0-0, Policy on Wetland Assessments for CERLA Actions		X
• 40 CFR 230, EPA Regulations on Discharge of Dredged or Fill Material into Navigable Waters	X	
• 33 CFR 320-330, Army Corps of Engineers Regulations Pertaining to Navigable Waters	X	
2. State Requirements • N.J.A.C. 7:7A Freshwater Wetland Protection Act Rules	X	
• N.J.A.C. 7:7E Coastal Zone Management Regulations for Coastal Wetlands	X	

Table 4. Preliminary Identification of Location-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
A. Threatened or Endangered Species 1. Federal Requirements • 50 CFR 17,200,402 Endangered and Threatened Wildlife	X	
• 40 CFR 230.30, Dredge/Fill Impacts on Threatened/Endangered Species	X	
• 40 CFR 6:302(h), NEPA Procedures for Endangered Species	X	
2. State Requirements • N.J.S.A. 23:2A-1, *et seq.*, Protection for Non-game and Endangered Species	X	
B. Natural Areas 1. Federal Requirements • 50 CFR 35.1 *et seq.*, Wilderness Act Regulations	X	
• 50 CFR 27, Wildlife Refuge Regulations	X	
• 40 CFR 6.302(e), NEPA Procedures for Wild and Scenic Rivers	X	
• 36 CFR 65,800, National Historic Preservation Act Regulations	X	
2. State Requirements • N.J.S.A. 13.8-45, *et seq.*, NJ Wild and Scenic Rivers Act	X	
• N.J.S.A. 13.8B-1, *et seq.*, NJ Conservation Restriction and Historic Preservation Restriction Act	X	

Table 5. Preliminary Identification of Action-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
I. ACTION-SPECIFIC All Remedial Actions State Requirements		
• N.J.A.C. 26E, Technical Requirements for Site Remediation	X	
B. Remedial Options for Soils, Residuals and Debris 1. On-site Disposal a. Federal Requirements • 40 CFR 761.75, TSCA Chemical Waste Landfill for PCB Containing Wastes	X	
• 40 CFR 761.202-218, PCB Waste Disposal Records and Reports	X	
• 40 CFR 761.61 Disposal of Polychlorinated Biphenyls-Proposed Rule (59 FR 62788, 12/6/94)		X
• 40 CFR 264.300-264.317 (Subpart N), RCRA Hazardous Waste Landfills	X	
• 40 CFR 264.90-264.101 (Subpart F), Releases from Solid Waste Management Units	X	
• 40 CFR 264.110-264.120 (Subpart G), Closure and Post-closure	X	
• 40 CFR 264.552-264.553 (Subpart S), Corrective Action Management Units	X	
• Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities, Advanced Notice of Proposed Rulemaking, 61 FR 19432 (May 1, 1996)		X
• 40 CFR 268, Land Disposal Restrictions	X	

Table 5. Preliminary Identification of Action-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
b. State Requirements • N.J.A.C. 7:26-2, General Disposal Requirements	X	
• N.J.A.C. 7:26-9.1 to 9.14, Requirements for Hazardous Waste Facilities	X	
• N.J.A.C. 7:26-10.8 and N.J.A.C. 7:26-11.4, Hazardous Waste Landfills	X	
2. Off-site Disposal a. Federal Requirements • 40 CFR 262, Subpart B, C and D, Standards Applicable to Generators of Hazardous Waste: The Manifest, Pre-transport Requirements, Record Keeping and Reporting	X	
• 40 CFR 172, 173, 178 and 179, Department of Transportation Requirements for Packaging, Labeling and Marking Hazardous Waste before Transport	X	
• 40 CFR 761.202-218, PCB Waste Disposal Records and Reports	X	
b. State Requirements • N.J.A.C. 7:26-3, Transportation Requirements	X	
3. Treatment a. Federal Requirements • 40 CFR 264.270-283, RCRA Land Treatment Regulations	X	
• 40 CFR 264.340-351, RCRA Incinerators	X	
• 40 CFR 268, Land Disposal Restrictions	X	
• 40 CFR 761.70, TSCA PCB Incineration	X	

	ARAR	TBC
• 40 CFR 761, Disposal of Polychlorinated Biphenyls-Proposed Rule (59 FR 62788, 12/6/94)		X
• Guidance on Remedial Actions for Superfund Sites with PCB Contamination (EPA 540 G-90-007)		X
b. State Requirements • N.J.A.C. 7:26-2B.8, Operational Requirements for Thermal Destruction Facilities	X	
• N.J.A.C. 7:26-10.7 and 7:26-11.5, Hazardous Waste Incinerators	X	
• N.J.A.C. 7:26-11.6, Thermal Treatment	X	
• N.J.A.C. 7:26-11.7, Chemical, Physical, and Biological Treatment	X	
• N.J.A.C. 7:27-8, Permit and Certification Rules of the Bureau of Air Pollution Control	X	
4. Capping/Containment with Institutional Controls a. State Requirements		
C. Remedial Options for Sediment: Natural Recovery, Capping/Containment, and Dredging		
1. Federal Requirements		
• EPA's Contaminated Sediment Management Strategy (EPA 823-R-94-001)		X
• 40 CFR Parts 230-231, Dredge or Fill Requirements (Section 404)	X	
2. State Requirements		
• Guidance for Sediment Quality Evaluations (3/91)		X
• N.J.A.C. 7:14, Water Pollution Control Act Regulations	X	

Table 5. Preliminary Identification of Action-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
• N.J.A.C. 7:13-4, Application Procedure for Stream Encroachment Permits	X	
• The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters, Draft, March 1996		X
D. Remedial Options for Ground Water 1. Natural Attenuation/Technical Impracticability a. Federal Requirements • 40 CFR 264.94, RCRA Alternate Concentration Limits	X	
• Guidance for Evaluating the Technical Impracticability of Ground Water Restoration (EPA 1540-R-93-080, September 1993)		X
• OSWER Memorandum: Consistent Implementation of the FY 1993 Guidance on Technical Impracticability of Ground Water Restoration at Superfund Sites, (Directive 9200.4-14, 1/19/95)		X
• Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities, Advanced Notice of Proposed Rulemaking, 61 FR 19432 (May 1, 1996)		X
b. State Requirements • N.J.A.C. 7:9-6.6, Exceptions to the Ground Water Classification System	X	
• Classification Exception Areas: Final Guidance, Memorandum from Rich Gimello (Assistant Commissioner to NJDEP Staff, 4/17/95)		X
• N.J.A.C. 7:14A-6.15, Criteria for Ground Water Protection and Response	X	

Table 5. Preliminary Identification of Action-Specific ARARs and TBCs. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

	ARAR	TBC
2. Reinjection of Treated Ground Water a. State Requirements • N.J.A.C. 7:14A-5, Underground Injection Control Program	X	
• N.J.A.C. 7:14A-6, Requirements for Discharges to Ground Water	X	
3. Discharge of Treated Ground Water to Surface Water a. Federal Requirements • 40 CFR Part 125, National Pollutant Discharge Elimination System	X	
b. State Requirements • N.J.A.C. 7:14A-9, Specific Procedures Applicable to Discharges to Surface Water	X	

Table 6A. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Soils†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	NJDEP[1] Unrestricted Use SCC	NJDEP[1] Restricted Use SCC	NJDEP[1] Impact to Ground Water SCC	USEPA[2] Generic SSL Inhalation/ Ingestion	USEPA[3] Generic SSL Migration to Ground Water	Proposed On-Property PRG	Proposed Off-Property PRG	Proposed Numeric DQO
Volatile Organic Compounds (mg/kg)								
Acetone	1000	1000	100	7800	0.8	100	100	50
Benzene	3	13	1	0.8	0.002	1	1	0.5
Toluene	1000	1000	500	650	0.6	500	500	250
Ethylbenzene	1000	1000	100	400	0.7	100	100	50
Xylenes	410	1000	10	410	9	10	10	5
2-Butanone	1000	1000	50			50	50	25
Semivolatile Organic Compounds (mg/kg)								
Phenanthrene								
Fluoranthene	2300	10000	100	3100	210	100	100	50
Pyrene	1700	10000	5000	2300	210	5000	1700	850
Chrysene	9	40	500	88	8	40	9	4.5
Benzoic Acid				310000	20	20	20	10
Bis(2-ethylhexyl)phthalate	49	210	100	46	180	100	49	24.5
Diethylphthalate	10000	10000	50	2000	23	50	50	25
Naphthalene	230	4200	100	3100	4	100	100	50
2-methylnapthalene								
Benzo(b)fluoranthene	0.9	4	50	0.9	4	50	2	1
Benzo(k)fluoranthene	0.9	4	500	9	49	4	0.9	0.45
Benzo(a)pyrene	0.66	0.66	100	0.9	0.4	0.66	0.66	0.33
Benzo(g,h,i)perylene								
Benzo(a)anthracene	0.9	4	500	0.9	0.08	4	0.9	0.45
Indeno(1,2,3-cd)pyrene	0.9	4	500	0.9	0.7	4	0.9	0.45
Butylbenzyl Phthalate	1100	10000	100	930	810	100	100	50
Acenapthene	3400	10000	100	4700	29	100	100	50
Anthracene	10000	10000	100	23000	590	100	100	50
Fuorene	2300	10000	100	3100	28	100	100	50
4-Methyl Phenol								
2,4-Dimethyl Phenol	1100	100000	10	1600	0.4	10	10	5
TPH	10000	10000	10000			10000	10000	5000
Polychlorinated Biphenyls (mg/kg)								
Total PCBs	0.49	2	50	1		2	0.49	0.245
Metals (mg/kg)								
Aluminum								
Arsenic	20	20		0.4	1	20	20	10
Barium	700	47000		5500	82	47000	700	350
Beryllium	2	2		0.1	3	2	2	1
Cadmium	1	100		78	0.4	100	1	0.5
Calcium								

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Table 6A. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Soils†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	NJDEP[1] Unrestricted Use SCC	NJDEP[1] Restricted Use SCC	NJDEP[1] Impact to Ground Water SCC	USEPA[2] Generic SSL Inhalation/ Ingestion	USEPA[3] Generic SSL Migration to Ground Water	Proposed On-Property PRG	Proposed Off-Property PRG	Proposed Numeric DQO
Chromium								
Cobalt								
Copper	600	600		3.4		600	600	300
Iron								
Lead	400	600		400		600	400	200
Magnesium								
Manganese								
Mercury	14	270				270	14	7
Nickel	250	2400		1600	7	2400	250	125
Potassium								
Selenium	63	3100		390	0.3	3100	63	31.5
Silver	110	4100		390	2	4100	110	55
Sodium								
Thallium	2	2			0.04	2	2	1
Vanadium	370	7100		550	300	7100	370	185
Zinc	1500	1500		23000	620	1500	1500	750

[1] New Jersey Department of Environmental Protection (NJDEP) Soil Cleanup Criteria (SCC) for Unrestricted Use, Restricted Use and Impact to Ground Water. Last revised July 11, 1996.

[2] The lower of the United States Environmental Protection Agency (USEPA) Generic Soil Screening Levels (SSL) for Ingestion and Inhalation.

[3] USEPA Generic SSL for Migration to Ground Water for a Dilution-Attenuation Factor of 1.

† Potential exposure routes for soil are provided on Figure 28.

mg/kg= Milligrams per Kilogram

DQO = Data Quality Objective. Equal to 50% of the PRG.

PRG = Preliminary Remedial Goal.

Table 6B. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Ground Water†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	NJDEP[1] GWQC	Federal[2] MCL	Proposed PRG	Proposed Numeric DQO
Volatile Organic Compounds (µg/ℓ)				
1,2-Dichloroethene	10	5	5	2.5
Acetone	700		700	350
Benzene	1	5	1	1[3]
Toluene	1000	1000	1000	500
Chlorobenzene	4		4	2
Ethylbenzene	700	700	700	350
Xylenes	40	1000	40	20
2-butanone	300		300	150
Trichloroethene	1	5	1	1[3]
Tetrachloroethene	1	5	1	1[3]
1,1,2-Trichloroethane	3		3	2[3]
Vinyl Chloride	5	2	2	2[3]
1,1Dichloroethane	70			
1,1 Dichloroethene	2	7	2	1
1,1,2,2 Tetrachloroethane	2		2	2[3]
1,2,4 Trimethylbenzene				
1,2,3 Trimethylbenzene				
1,2-Dichlorobenzene	600		600	300
1,2-Dibromo-3-chloropropane				
1,2-Dibromomethane				
2-Chlorotoluene				
4-Chlorotoluene				
1,2,3-Trichloropropane				
2-Hexanone				
Isopropyl benzene				
n-Propyl benzene				
n-Butyl benzene				
Dichlorofluoromethane				
Chloroform	6		6	3
sec-Butyl Benzene				
p-Isopropyl Toluene				
Carbon Disulfide				
Isopropyl Benzene				
Semivolatile Organic Compounds (µg/ℓ)				
Phenanthrene				
Di-n-butyl phthalate	900		900	450
Fluoranthene	300		300	150
Pyrene	200		200	100
Benzo(a)anthracene				
Chrysene				
Bis(2-ethylhexyl)phthalate	30		30	15
Diethylphthalate		6	6	3
Naphthalene				
2-methylnapthalene				
Benzo(a)fluoranthene				
Benzo(b)fluoranthene				
Benzo(k)fluoranthene				
Benzo(a)pyrene		0.2	0.2	0.1
Benzo(g,h,i)perylene				
Indeno(1,2,3-cd)pyrene				
Oil and grease	None Noticeable		None Noticeable	
Fluorene	300		300	150
Di-n-Octylphthalate	100		100	50
Dimethylphthalate				
Phenol	4000		4000	2000

Table 6B. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Ground Water†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	NJDEP[1] GWQC	Federal[2] MCL	Proposed PRG	Proposed Numeric DQO
1,2-Dichlorobenzene	600		600	300
2,4-Methyl Phenol				
4-Methyl Phenol				
Anthracene	2000		2000	1000
Benzoic Acid				
Benzyl-Butyl Phthalate				
Bis(2-Chloroethyl)Ether	10		10	5
Isophrone	100		100	50
Benzyl Alcohol	2000		2000	1000
2,4-Dimethyl Phenol	100		100	50
2-Methyl Phenol				
4-Methyl Phenol				
Polychlorinated Biphenyls (µg/kg)				
Arochlor 1254				
Arochlor 1260				
Total PCBs	0.5	0.5	0.5	0.25
Metals (mg/kg)				
Aluminum	200		200	100
Antimony	20	6	6	3
Arsenic	8	50	8	4
Barium	2000	2000	2000	1000
Beryllium	20	4	4	2
Cadmium	4	5	4	2
Chromium	100	100	100	50
Iron	300		300	150
Lead	10		10	5
Manganese	50		50	25
Nickel	100		100	50
Thallium	10		10	5
Zinc	5000		5000	2500

[1] The Higher of the Ground Water Quality Criteria For Class IIA Aquifers or Practical Quantitation Level as Specified in N.J.A.C. 7:9-6.7(c).
[2] Federal Maximum Contaminants Levels at 40 CFR 141
[3] Laboratory Minimum Detection Limit.
† Potential exposure routes for soil are provided on Figure 28.
µg/ℓ = Micrograms per liter
DQO = Data Quality Objective. Equal to 50% of the PRG.
PRG = Preliminary Remedial Goal.

Table 6C. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Surface Water†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	New Jersey[1] SWQC	DRBC[2] SQO	Ambient[4] Water Quality Criteria Freshwater	Ambient[5] Water Quality Criteria Salt Water	Ambient[6] Water Quality Criteria Human Health	Proposed PRG Little Timber Creek	Proposed PRG Gaventa And Swindell Ponds	Proposed Numeric DQO
Volatile Organic Compounds (µg/ℓ)								
Acetone								
Benzene	0.15	12.5[3]			71	12.5	0.15	1[7]
Toluene	7440				200000		7440	3720
Ethylbenzene	3030				29000		3030	1515
1,2,3-Trichlorobenzene								
2-Chlorotoluene								
Carbon Disulfide								
2-Hexanone								
Semivolatile Organic Compounds (µg/ℓ)								
Di-n-butyl phthalate					12000			
Pyrene	797				11000		797	398.5
Bis(2-ethylhexyl)phthalate	1.76	1.04[3]			5.9	1.04	1.76	0.52
Naphthalene								
Anthracene					110000	110000	110000	55000
Di-n-octyl phthalate								
Polychlorinated Biphenyls (µg/ℓ)								
Arochlor 1254			0.014	0.03	0.000045			
Arochlor 1260			0.014	0.03	0.000045			
Total PCBs	0.014	0.03				0.03	0.014	0.007
Metals (µg/ℓ)								
Aluminum								
Antimony	12.2				4300		12.2	6.1
Arsenic	0.017	36	190	36	0.14	36	0.017	0.0085
Barium	2000						2000	1000
Beryllium		0.0232[3]				0.0232		0.0114
Cadmium	10	9.3	1	9.3		9.3	10	4.6
Calcium								
Chromium	160						160	80
Cobalt								
Copper		3.4	11	2.4		3.4		1.7
Iron								
Lead	5	8.5	2.5	8.1		8.5	5	2.5
Magnesium								
Manganese	100						100	50
Mercury	0.144	0.025	0.012	0.025	0.15	0.025	0.144	0.013
Nickel	516	8.3	160	8.2	4600	8.3	516	42
Potassium								
Selenium	10	71	5	71		71	10	5

Table 6C. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Surface Water†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	New Jersey[1] SWQC	DRBC[2] SQO	Ambient[4] Water Quality Criteria Freshwater	Ambient[5] Water Quality Criteria Salt Water	Ambient[6] Water Quality Criteria Human Health	Proposed PRG Little Timber Creek	Proposed PRG Gaventa And Swindell Ponds	Proposed Numeric DQO
Sodium								
Vanadium								
Zinc		86	110	81		86		43
Cyanide	22		5.2	1	220000		22	11

[1] New Jersey Surface Water Quality Criteria (SWCQ) for FW2 Waters at N.J.A.C. 7:9B-1.14.

[2] Delaware River Basin Commission (DRBC) Stream Quality Objectives(SQO) for Toxic Pollutants for the Protection of Aquatic Life in the Delaware River Estuary (Marine Objectives) unless otherwise noted

[3] DRBC Stream Quality Objectives for Carcinogens in the Delaware River Estuary (Marine Objectives).

[4] Continuous Concentration Ambient Water Quality Criteria for Freshwater at 40 CFR 131.36.

[5] Continuous Concentration Ambient Water Quality Criteria for Saltwater at 40 CFR 131.36.

[6] Human Health Ambient Water Quality Criteria for Consumption of Organisms at 40 CFR 131.36.

[7] Laboratory Minimun Detection Limit.

† Potential exposure routes for surface water are provided on Figure 28.

µg/ℓ = Micrograms per liter

DQO = Data Quality Objective. Equal to 50% of the PRG.

PRG = Preliminary Remedial Goal.

Table 6D. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Sediments†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	Ontario[1] LEL	Long *et. al.*[2] ER-L	ORNL[3] SQB	Ingersol *et. al.*[3] TEL-HA28	Washington[4] State AET-HA	Washington[4] State AET-MT	Proposed PRG	Proposed DQO
Volatile Organic Compounds (µg/kg)								
1,2-Dichloroethene			23				23	11.5
Acetone			64				64	32
Benzene			52				52	26
Toluene			786				786	393
Chlorobenzene			714				714	357
Ethylbenzene			4360				4360	2180
Xylenes			1210				1210	605
Hexane			12780				12780	6390
2-butanone								
Trichloroethene			1007				1007	503.5
Tetrachloroethene			2730				2730	1365
1,1,2-Trichloroethane			1310				1310	655
Semivolatile Organic Compounds (µg/kg)								
Phenanthrene	560	240		19	210000	15000	560	280
Di-n-butyl phthalate			42100				42100	21050
Fluoranthene	750	600		31	130000	21000	750	375
Pyrene	490	665		44	85000	23000	490	245
Benzo(a)anthracene	320	261		16	33000	7700	320	160
Chrysene	340	384		27	39000	11000	340	170
2-cyclohexen-1-01								
2-cyclohexen-1-One								
1-H-3a,7-Methanoazulene,2,3								
Hexadeconic Acid								
Bis(2-ethylhexyl)phthalate								
Diethylphthalate			634				634	317
Naphthalene		160	407		2600	46000	407	203.5
2-methylnapthalene								
Benzo(a)fluoranthene								
Benzo(k)fluoranthene	240						240	120
Benzo(a)pyrene	370			32	25000	11000	370	185
Benzo(g,h,i)perylene	170				21000	1400	170	85
Limonene								
Indeno(1,2,3-cd)pyrene	200				15000	760	200	100
Cineole								
Pentadaconic acid								
2-phenanthrenol,4b,5,6,7,8								
Tridecone								
Alpha-lobene								
Total PAHs	4000	4022			700000	170000	4000	2000
Low Molecular Weight PAHs		552			440000	74000	552	276
High Molecular Weight PAHs		1700			310000	91000	1700	850
TPH								
Oil and grease	0.15%						0.15%	0.00075

Table 6D. Summary of Preliminary Remedial Goals and Numeric Data Quality Objectives for Sediments†. BROS Superfund Site; Bridgeport, New Jersey.

Analyte	Ontario[1] LEL	Long *et. al.*[2] ER-L	ORNL[3] SQB	Ingersol *et. al.*[3] TEL-HA28	Washington[4] State AET-HA	Washington[4] State AET-MT	Proposed PRG	Proposed DQO
Polychlorinated Biphenyls (µg/kg)								
Arochlor 1254	60				350	7.3	60	30
Arochlor 1260	5						5	2.5
Total PCBs		50		32	820	21	50	25
Metals (mg/kg)								
Aluminum								
Antimony					64	3	3	1.5
Arsenic	6	8.2		11	150	40	6	3
Barium			20				20	10
Beryllium								
Cadmium	0.6	1.2		0.58	12	7.6	0.6	0.3
Calcium								
Chromium	26	81		36	280		26	13
Cobalt								
Copper	16	34		28	840		16	8
Iron			3%				3%	1.50%
Lead	31	46.7		35	720	260	31	15.5
Magnesium								
Manganese	460				1800		460	230
Mercury	0.2	0.15			2.7	0.56	0.2	0.1
Nickel	16	20.9		20			16	8
Potassium								
Selenium								
Silver	0.5	1			4.5		0.5	0.25
Sodium								
Thallium								
Vanadium								
Zinc	120	150		98	3200	520	120	60
Cyanide	0.1						0.1	0.05

[1] Indicates Lowest Effects Level (LEL) from *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario*, Ontario Ministry of Environment and Energy, August 1993 used as Preliminary Remedial Goal (PRG).

[2] Indicates LEL not established. Effects Range Low (ER-L) from *Incidence of Adverse Biological Effects Within Ranges of Chemicals in Marine and Estuarine Sediments* by Long E. R., MacDonald, D. D, Smith, S. L., and Calder, F. D. 1993, Environmental Management, V. 19, No. 1.

[3] Indicates LEL and ER-L not established. Sediment Quality Benchmark (SQB) from Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota, Environmental Sciences Division-Oak Ridge National Laboratory, June 1994 used as PRG.

[4] Apparent Effects Thresholds (AET) for Hyalella azetca (HA) and Microtox (MT) from *Creation and Analysis of Freshwater Sediment Quality Values in Washington State*, Washington State department of Ecology, publication No. 97-323a, July 1997.

† Potential exposure routes for sediment are provided on Figure 28 of the Phase 2 RI/FS Work Plan.

µg/kg = Micrograms per kilogram.

mg/kg = Milligrams per kilogram.

DQO = Data Quality Objective. Equal to 50% of the PRG.

PRG = Preliminary Remedial Goal.

Table 7. Preliminary Screening of Remedial Technologies. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Technologies/Process Options	Media: Ground Water	LNAPL	DNAPL	Surface Water	Sediments /Wetlands	Incinerator Ash	Soils	Lagoon Residuals	Advantages	Limitations	Screening: Effectiveness	Implementability	Relative Cost	Retained?
No Action														
No Action	✓	✓	✓	✓	✓	✓	✓	✓	• Required by NCP as a baseline for comparison. • Installation of public water supply near the site has reduced exposure.	• Certain locations of the site may act as a continuing source. • Downgradient receptors may still be a concern. • Possible continued migration of chemicals of concern.	unlikely	high	low	Yes
Institutional Options														
Monitoring	✓	✓	✓	✓	✓	✓	✓	✓	• Monitor the media to ensure that human health is protected. • Should be included as a component of other remedial actions to assess effectiveness over time.	• Long-term monitoring likely necessary.	high	high	low	Yes
Fencing/Warning Signs	✓	✓	✓	✓	✓	✓	✓	✓	• Restricts access to trespassers, mitigating a potential exposure scenario. • Easily implemented and requires little maintenance.	• Reliability predicated on proper maintenance.	high	high (already completed for Borrelli property)	low	Yes
Deed /Water Use Restrictions (Classification Exception Area)	✓	✓	✓	✓	✓	✓	✓	✓	• Restriction of site use to industrial and/or commercial purposes. • Notification of restriction of future use of ground water via Classification Exception Area required.	• Depends upon implementation and results of receptor analysis	moderate	high (already completed for Borrelli property)	low	Yes
Reclassification	✓								• Reclassify aquifer system or portions thereof to allow for alternative cleanup levels.	• Limited applicability and low probability of acceptance due to federally-designated sole source aquifer.	moderate	unlikely	low	Yes
Alternative Residential Water Supply	✓								• Nearby residential supplies have already been replaced. Public supply will likely need to be extended for additional long-term exposure protection.	• Exposure scenarios not yet known.	moderate	high (already completed in some areas)	moderate	Yes
Containment														
Dust Control				✓	✓	✓	✓		• Limits an exposure pathway. • May be necessary during excavation/soil handling-retained for this purpose only.	• Exposure to airborne contaminants carried on dust is not considered a significant risk to human health or the environment to date.	moderate	high	low	Yes (for temporary use)
Surface Controls • diversion/retention • grading				✓	✓	✓	✓	✓	• Effective for control of surface run-off. • Can reduce transport of impacted soils to surface water/wetlands and impacted sediments through surface water.	• Surface water retention design and discharge configuration must consider water balance and scouring in wetlands. • Limited effectiveness for subsurface contaminants (lagoon residuals) except in limiting infiltration.	moderate	high	low	Yes
Capping • asphalt cap • multilayered cap • synthetic cap • clay cap • inert cover • vegetated cap	✓			✓	✓	✓	✓	✓	• Reduces mobility by reducing infiltration and potential contaminant leaching. • Eliminates dermal contact exposure pathway. • Reduces surface transport of impacted soils into surface water and wetlands via storm water and ground water interaction..	• May not eliminate all migration pathways. • Although vegetated caps can include herbaceous wetlands species, limited applicability of capping for wetlands sediments due to changes in hydrology and shift in plant community.	moderate	high (except for wetlands areas)	low	Yes
Vertical Barriers • slurry wall • sheet piling • grout curtain	✓	✓	✓	✓	✓	✓	✓	✓	• Can contain source and reduce migration pathways.	• More effective if keyed into low permeability layer. Intermittent clay layers may limit use of vertical barriers. • Required depths could make this option prohibitive, particularly for deeper zones.	moderate	moderate	high	Yes
Subsurface Horizontal Barriers • liners • grout injection	✓				✓	✓	✓	✓	• Limits vertical migration of contaminants in similar manner as capping.	• Potential for modifications to shallow ground-water flow and likely potential to detrimentally impact wetlands must be evaluated.	unlikely	moderate	high	No
Controlled Flooding	✓			✓	✓				• Raising the surface water level in a controlled manner can limit exposure pathways. • Could be combined with revegetation (see below).	• Potential for modifications of shallow ground-water flow and potential to impact wetlands must be evaluated.	moderate	high	moderate	Yes
Armoring				✓	✓				• Consists of installing layer of material on top of sediment to prohibit direct contact with surface water, decrease human health/ecological contact, and minimize sediment transport. • Can be augmented with revegetation.	• Potential for modifications to wetlands must be evaluated.	moderate	moderate	moderate	Yes

Table 7. Preliminary Screening of Remedial Technologies. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Technologies/Process Options	Media: Ground Water	LNAPL	DNAPL	Surface Water	Sediments /Wetlands	Incinerator Ash	Soils	Lagoon Residuals	Advantages	Limitations	Screening: Effectiveness	Implementability	Relative Cost	Retained?
In-situ treatment														
Natural remediation	✓	✓	✓	✓	✓	✓	✓	✓	• Certain media and site locations may be naturally remediating. • Has gained recognition of effectiveness at appropriate sites.	• Requires monitoring and evaluation. • Risks of exposure pathways must be well understood.	moderate	high	low	Yes
Revegetation				✓	✓	✓	✓		• Effective at limiting sediment transport. • Restoration of species diversity and may increase wetland function and value.	• Interactions with ecosystems must be evaluated.	moderate	high	moderate	Yes
Oxygen Release Compounds	✓								• Hydrated magnesium peroxide placed in wells releases oxygen to the ground water to stimulate bioremediation. • Use of oxygen release compounds near property line could assist off-site remediation, particularly for petroleum hydrocarbons.	• May not treat chlorinated compounds or metals.	moderate	high	low	Yes
Biosparging	✓								• Proven effective for removal of VOCs, although aerobic/anaerobic alternatives must be evaluated.	• Susceptible to iron fouling and biological fouling - may require special O&M procedures. • Presence of clay lenses and silt layers may restrict vapor movement and create preferential flow paths • Flow rates and sparge locations must be established to avoid short-circuiting to surface water or along stratigraphic units.	moderate	high	moderate	Yes
Bioremediation via injection	✓	✓	✓						• Innovative technology showing promise by injecting select microbes or nutrients.	• Requires pilot testing	moderate (site-specific)	high	moderate	Yes
Soil Vapor Extraction	✓								• Effective for removal of VOCs and certain SVOCs with higher Henry's Constants. • Can be combined with ground-water pumping to increase depth/zone of influence.	• Will not remove metals, PCBs, or certain SVOCs. • Heterogeneous soils and low soil permeabilities can limit effectiveness. • Off-gas treatment is typically necessary to prevent emissions. • Shallow depth to ground-water limits effectiveness.	moderate(if combined with ground water measures)	moderate	moderate	Yes
Air Sparging	✓								• Effective technology for removal of VOCs from ground water. • Most effective if coupled with SVE discussed above. • An excavated or homogenized trench can be used to overcome certain limitations.	• Susceptible to iron fouling and clogging of injection well and surrounding media; especially at iron concentrations detected at the Site. • Presence of clay lenses and silt layers will restrict vapor movement and create preferential flow paths • More conducive for shallow ground water.	moderate	moderate	moderate	Yes
Steam Stripping	✓								• Similar to SVE described above but more effective for removal of SVOCs because of elevated temperatures.	• Similar to SVE described above. • More extensive equipment and operation needed to generate steam.	moderate	moderate	high	Yes
Reaction wall	✓								• Installation of materials (i.e. zero-valent iron) creates chemical reduction.	• Effective for select compounds.	moderate	moderate	high	Yes
Soil Flushing	✓								• Injection of water, solvent and/or surfactant can enhance contaminant recovery.	• Heterogeneity of soils can complicate injection and recovery of leachate. • Limited effectiveness for metals, not a proven technology. • Certain surfactants have been shown to clog soil pores and preclude further flushing.	moderate	moderate	high	Yes
Oxidation/Reduction	✓	✓				✓	✓	✓	• Introduction of chemical compounds (i.e., permanganate, hydrogen peroxide) break down contaminants to mineral constituents. • Residual oxygen generated can foster biodegradation.	• Heterogeneity of soils can complicate injection. • Chemistry must be thoroughly evaluated.	moderate	moderate	high	Yes
Solidification • cement-based agents • silicate-based agents • sorptive agents	✓				✓	✓	✓	✓	• Effective for immobilization of metals and some organics.	• Soils handling issues must be considered for on-site disposal. • Not appropriate for soils underlying incineration ash. • Dewatering requirements for sediments will increase costs.	moderate	moderate	high	Yes
Vitrification					✓	✓	✓	✓	• Isolation of contaminants in a glassy, solid matrix through electrical melting will provide long term exposure protection.	• Recovery and treatment of off-gas necessary to control emissions. • Increased costs for saturated materials - sediments and saturated soils. • Requires treatment/disposal of an aqueous scrub solution; no sewer available on-site. • Poor effectiveness when contaminants are near the surface.	unlikely	moderate	1	No

Table 7. Preliminary Screening of Remedial Technologies. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Technologies/Process Options	Media: Ground Water	Media: LNAPL	Media: DNAPL	Media: Surface Water	Media: Sediments /Wetlands	Media: Incinerator Ash	Media: Soils	Media: Lagoon Residuals	Advantages	Limitations	Screening: Effectiveness	Screening: Implementability	Screening: Relative Cost	Retained?
Excavation/Ex-situ Treatment/Disposal														
Excavation					✓	✓	✓		• Can reduce risks from human exposure. • Can eliminate potential sources to other media.	• Excavated soil/sediment requires treatment/disposal. Dewatering sediment would likely be required. • Excavating Lagoon residuals would be prohibitive. • Removing sediment from wetlands or surface-water bodies could have negative ecological ramifications. • Long-term effectiveness mitigated by potential for releases of VOCs from saturated zone, recontaminating unsaturated soils.	unlikely	moderate	moderate	Yes
Ex-Situ SVE					✓	✓	✓		• Similar to SVE described above, but performed ex-situ. • Certain conditions can be better controlled ex-situ.	• Similar limitations to in-situ SVE. • Dewatering of sediments as part of SVE would be required.	moderate	high	moderate	Yes
Biological Treatment • composting • landfarming					✓	✓	✓		• Biodegradation can be a slow process, but recent developments warrant continued evaluation.	• Aerobic biodegradation ineffective for chlorinated VOCs, metals, PCBs.	moderate	moderate	moderate	Yes
On-Site Landfill					✓	✓	✓		• Greatly reduces off-site transportation requirements.	• Pretreatment of wastes may be necessary prior to disposal to meet RCRA requirements. • Proximity to 100 year flood plain, wetlands, and residential communities will complicate implementation. Shallow depth to ground water restricts this option.	high	high	moderate	Yes
Thermal Treatment - Thermal Desorption					✓	✓	✓		• Effective removal of volatile organic compounds from soil, removal of some metals; further reducing risks associated with soils. • Can be effective for removal of PCBs at higher temperatures.	• Not effective for removal of metals. • Requires treatment/disposal of water recovered from soil/sediment. • May not be available as a RCRA-permitted off-site disposal option.	moderate	moderate	moderate	Yes
Off-Site Landfill					✓	✓	✓		• Allows for removal of contaminants from the site. • Readily implementable, will require approval of waste stream by landfill.	• Pretreatment of wastes may be necessary prior to disposal. • Certain constituents may trigger land disposal restrictions.	high	high	high	Yes
Ex-situ Solidification/Stabilization					✓	✓	✓		• Improves waste handling characteristics. • Effective for immobilizing metals.	• Treated soils will require either on-site or off-site disposal.	moderate	moderate	High	Yes
Physical Treatment - Soil Washing • solvent washing • surfactants					✓	✓	✓		• Uses available methods and equipment to reduce volume.	• Residual solvents limit soil reuse options. • Concern for VOC emissions during operation of process. • Recovered leachate requires treatment/disposal. • Organic-rich soils and fine particles will increase cost and reduce effectiveness.	unlikely	moderate	very high	No
Chemical Treatment - Oxidation/Reduction					✓	✓	✓		• Potentially improved performance over in-situ methods described above.	• Limited effectiveness for certain organics, PCBs and heavy metals. • Handling soil and chemicals can be challenging.	moderate	moderate	high	No
Thermal Treatment - Pyrolysis					✓	✓	✓		• Effective destruction of organic compounds in the absence of oxygen. • A destructive technology which reduces the volume, toxicity and mobility of contaminants.	• Requires treatment of off-gas and disposal of residual ash. • Permitting and space requirements mitigate use as an on-site technology. Not readily available as a RCRA-permitted off-site disposal option.	moderate	unlikely	high	No
Thermal Treatment - Incineration					✓	✓	✓		• Effective destruction of organic compounds. • A destructive technology which reduces the volume, toxicity and mobility of contaminants.	• Requires treatment of off-gas and disposal of residual ash. • Permitting and local concerns mitigate use as an on-site technology. Will be retained as an off-site disposal option.	high	moderate (off-site)	very high	Yes (off-site)
Extraction/Treatment /Discharge														
Ground-water Extraction (vertical wells/horizontal wells/trenches)	✓	✓	✓						• Proven to be effective in containment/control of ground-water migration.	• Extracted ground water requires treatment prior to discharge. • A long-term remedial approach; restricted by size of capture zone, permeability/transitivity of geologic units; adsorptive and ion exchange reactions, and diffusion kinetics. • Water allocation permits are required for higher extraction rates and will be difficult to obtain given trends in the area. • Extraction will likely have significant detrimental effects on nearby surface water bodies (wetlands). • Upgradient contaminant plume at Chemical Leaman Tank Lines site must be considered and isolated from pumping center capture zones.	high (for containment)	unlikely	moderate	Yes (for localized areas requiring containment)

Table 7. Preliminary Screening of Remedial Technologies. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Technologies/Process Options	Media: Ground Water	LNAPL	DNAPL	Surface Water	Sediments /Wetlands	Incinerator Ash	Soils	Lagoon Residuals	Advantages	Limitations	Screening: Effectiveness	Implementability	Relative Cost	Retained?
Enhanced Removal - Chemical Extraction	✓	✓							• Use of solvents/surfactants mobilize contaminants in the saturated zone.	• Not demonstrated to be effective for metals. • Precise hydrologic control necessary to recover contaminants and residual solvents, especially where contaminant mass is near base of aquifer; not practical for BROS site due to geologic conditions. • Clogging of injection wells may occur, especially in high iron environments which exist at the site.	unlikely	moderate	moderate	No
Enhanced Removal - Hydrofracture	✓	✓							• Use of pressure or explosive charges to create fractures in overburden; increasing hydraulic conductivity.	• Relatively expensive given width of plume. Limited benefit due to high permeability of aquifer systems. • Can create preferential flow paths that increase transport of chlorinated VOCs if DNAPLs are likely.	unlikely	moderate	moderate	No
Enhanced Removal- electric induction	✓								• Use induction of electric current to increase ground water flow in water with ionic strength.	• Sandy conditions at site likely do not require enhanced removal.	unlikely	moderate	high	No
Physical Treatment - Sedimentation • settling basins • clarifiers	✓								• Effective, proven technology for the removal of suspended solids.	• Solids require further treatment/disposal.	moderate	moderate	moderate	Yes
Physical Treatment - Filtration • gravity flow filters • pressure filters	✓								• Effective for removal of suspended solids.	• Filters must be backwashed. Solids are then removed from backwash for disposal.	moderate	moderate	moderate	Yes
Physical Treatment - Phase Separation • oil/water separators	✓	✓	✓						• Non-aqueous phase liquids have been identified at the site and may require treatment. • Proven technology for liquid/liquid separation.	• Recovered product requires further treatment/disposal	moderate	moderate	moderate	Yes
Physical Treatment - Membrane Technologies • reverse osmosis • ultra filtration	✓	✓	✓						• Proven technology for removal of metals and some organic compounds. Best organic performance for high molecular weight organics and multivalent ions.	• Pretreatment will be required adjust pH and to remove iron and manganese, to remove particulates. • Useful as a pretreatment technology prior to UV/peroxide but susceptible to fouling, plugging and chemical attack. • Substantial quantity of reject solution will require further treatment.	moderate	moderate	moderate	Yes
Physical Treatment - Activated Carbon Adsorption	✓								• Proven technology for removal of many organic contaminants.	• Susceptible to fouling and plugging. Pretreatment required to remove iron, manganese, and particulates and to prevent biofouling. • A transfer technology, carbon must be further treated/regenerated to remove adsorbed organic compounds. Exposures associated with regeneration and transportation can be significant.	moderate	moderate	moderate	Yes
Physical Treatment - Air Stripping	✓								• Effective technology for removal of VOCs. • Some systems are resistant to biofouling and to clogging from iron precipitates. • Relatively simple to operate.	• Iron concentrations at the Site complicate options to these systems. • Off-gas requires treatment and air pollution control permit.	moderate	moderate	moderate	Yes
Physical Treatment - Steam Stripping	✓								• Effective technology for removal of volatile organic compounds.	• Requires a source of steam, significantly increasing operating costs and necessitating more intensive operations. • Susceptible to iron and biological fouling. • Treated waste water can enhance mobilization of in-situ contaminants if reinjected but increased temperature often leads to biofouling of injection system. • Off-gas requires treatment. • Air pollution control permit is required.	moderate	moderate	high	Yes
Extraction/Treatment/ Discharge (continued)														
Chemical Treatment - Precipitation	✓								• Effective, proven technology for the removal of most metals. Useful as a pretreatment process.	• Precipitate must be removed from water stream; typically disposed of as a regulated waste.	moderate	moderate	moderate	Yes
Chemical Treatment - Neutralization	✓								• pH adjustment for pretreatment and/or post treatment; especially following precipitation/sedimentation or preceding biological treatment, carbon adsorption, and ion exchange. • Relatively simple process performed with readily available equipment.	• Chemical handling creates health and safety issues.	moderate	moderate	moderate	Yes

Table 7. Preliminary Screening of Remedial Technologies. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Technologies/Process Options	Media								Advantages	Limitations	Screening			Retained?
	Ground Water	LNAPL	DNAPL	Surface Water	Sediments /Wetlands	Incinerator Ash	Soils	Lagoon Residuals			Effectiveness	Implementability	Relative Cost	
Chemical Treatment - Ion Exchange	✓								• Effective technology for removal of a broad range of ionic species and some organic compounds. • A transfer technology, waste materials generated during resin regeneration require further treatment/disposal. • Not impacted by variable waste streams.	• Requires pretreatment to remove suspended solids. • Resin replacement and regeneration can be expensive and time consuming, even at modest flow rates.	moderate	moderate	high	Yes
Chemical Treatment - UV/Peroxide Oxidation	✓	✓	✓						• Effective technology for removal of VOCs. • Relatively simple to operate, but does require special handling of hydrogen peroxide. • No off-gas requiring treatment. • A permanent destruction technology, not just a transfer technology.	• Pretreatment required to prevent iron fouling of UV chambers. Post-treatment pH adjustment may be necessary.	moderate	moderate	moderate	Yes
Biological Treatment - Anaerobic Treatment - Activated Sludge	✓	✓							• Effective technology for removal of many contaminants.	• Relatively slow process. • Generation of methane and hydrogen sulfide gases a safety and nuisance odor concern. • Performance is unpredictable and post-treatment is necessary to address organic residuals.	moderate	moderate	moderate	Yes
Biological Treatment - Aerobic Treatment	✓	✓							• Effective for removal of many organic compounds and some metals.	• Disposal of biological sludge is necessary.	moderate	moderate	moderate	Yes
Constructed Wetlands	✓			✓	✓				• Effective technology for removal of organics and metals. Employs physical, chemical and biological processes. • Can be employed as a stand alone system or for polishing of treated ground water. • Creation of wildlife habitat provides a benefit to community acceptance. • Typically low O&M costs compared to other treatment systems.	• Requires significant land area and an ultimate discharge point.	moderate	moderate	moderate	Yes
Discharge - Upper PRM Aquifer	✓								• Technically feasible based upon aquifer characteristics.	• Shallow depth to water and proximity of wetlands present a concern for short circuiting for reinjection wells. • Limited surface area for reinjection gallery, especially due to residual sources in former lagoon. • Aggressive treatment requirements are likely necessary due to adjacent wetlands. • Significant cost of reinjection system O&M due to high iron concentrations in ground water.	moderate	moderate/unlikely	moderate	Yes
Discharge - Upper Middle PRM Aquifer	✓								• Technically feasible based upon aquifer characteristics.	• Aggressive treatment requirements are likely due to NJDEP criteria, unless injection upgradient of the plume is likely. • Significant cost of reinjection system O&M due to high iron concentrations in ground water.	moderate	moderate/unlikely	moderate	Yes
Discharge - Lower Middle PRM Aquifer	✓								• Less stringent treatment requirements are likely due to high salinity of this aquifer. • Technically feasible based upon aquifer characteristics.	• Significant cost of reinjection system O&M due to high iron concentrations in ground water.	moderate	moderate/unlikely	moderate	Yes
Discharge to Little Timber Creek	✓								• Timber Creek is close to the site, simplifying implementation.	• Stringent effluent limitations are likely due to proximity of wetlands.	moderate	moderate/unlikely	moderate	Yes
Discharge - Delaware River	✓								• Discharge limitations likely to be less rigorous than for discharge to Little Timber Creek.	• Delaware River is far from site, complicating implementation.	moderate	moderate/unlikely	moderate	Yes
Discharge - Publicly Owned Treatment Works	✓								• Straightforward implementation.	• No sewer system available at the site. • Municipal Sewer Authorities are restricting access as part of pretreatment/industrial discharge programs.	moderate	moderate	moderate	Yes

Table 8. Preliminary Assembly of Remedial Alternatives. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Media	Technology Type	Alternatives 1	2	3	4	5	6	7	8
Soils	No Action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	Fencing/Warning Signs		•	•	•	•	•	•	•
	Deed Restrictions		•	•	•	•	•	•	•
	Source Control								
	Containment		•	•			•		
	In-Situ Treatment				•			•	
	Excavation/Treatment					•			•
	Residuals Management								
	Containment			•	•	•			
	In-Situ Treatment						•	•	
	Excavation/Treatment								•
Incinerator Ash	No Action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	Fencing/Warning Signs		•	•	•	•	•	•	•
	Deed Restrictions		•	•	•	•	•	•	•
	Source Control								
	Containment			•		•	•		•
	In-Situ Treatment				•			•	
	Excavation/Treatment								
	Residuals Management								
	Containment			•	•	•			•
	In-Situ Treatment						•	•	
	Excavation/Treatment								

Note:
The preliminary assembly of remedial alternatives is based upon the preliminary screening of candidate technologies (Table 7) and the considerations outlined in Section 4.4 of this Work Plan.

Table 8. Preliminary Assembly of Remedial Alternatives. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Media	Technology Type	Alternatives 1	2	3	4	5	6	7	8
NAPL	No action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	CEA		•	•	•	•	•	•	•
	Alternative Water Supply		•	•	•	•	•	•	•
	Source Control								
	Containment			•		•	•		
	Natural Remediation			•	•	•	•	•	•
	In-Situ Treatment				•			•	
	Extraction/Treatment								•
	Residuals Management								
	Containment			•	•	•			
	Natural Remediation			•	•	•	•	•	•
	In-Situ Treatment						•	•	
	Extraction/Treatment								•
Lagoon Residuals	No Action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	Fencing/Warning Signs		•	•	•	•	•	•	•
	Deed Restrictions		•	•	•	•	•	•	•
	Source Control								
	Containment			•			•		
	In-Situ Treatment				•			•	
	Excavation/Treatment					•			•
	Residuals Management								
	Containment			•	•				
	In-Situ Treatment						•	•	
	Excavation/Treatment								•

Note:
The preliminary assembly of remedial alternatives is based upon the preliminary screening of candidate technologies (Table 7) and the considerations outlined in Section 4.4 of this Work Plan.

Table 8. Preliminary Assembly of Remedial Alternatives. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Media	Technology Type	Alternatives 1	2	3	4	5	6	7	8
Ground Water	No action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	CEA		•	•	•	•	•	•	•
	Alternative Water Supply		•	•	•	•	•	•	•
	Source Control								
	Containment			•			•		
	Natural Remediation			•	•	•	•	•	•
	In-Situ Treatment				•			•	
	Extraction/Treatment					•			•
	Residuals Management								
	Containment			•	•	•			
	Natural Remediation			•	•	•	•	•	•
	In-Situ Treatment						•	•	
	Extraction/Treatment								•
Surface Water	No action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	Fencing/Warning Signs		•	•	•	•	•	•	•
	Deed Restrictions		•	•	•	•	•	•	•
	Source Control								
	Containment		•	•		•	•		•
	In-Situ Treatment				•			•	
	Residuals Management								
	Containment			•	•	•			
	In-Situ Treatment						•	•	•

Note:
The preliminary assembly of remedial alternatives is based upon the preliminary screening of candidate technologies (Table 7) and the considerations outlined in Section 4.4 of this Work Plan.

Table 8. Preliminary Assembly of Remedial Alternatives. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Media	Technology Type	Alternatives 1	2	3	4	5	6	7	8
Sediments	No action	•							
	Institutional Controls								
	Monitoring		•	•	•	•	•	•	•
	Fencing/Warning Signs		•	•	•	•	•	•	•
	Deed Restrictions		•	•	•	•	•	•	•
	Source Control								
	Containment			•			•		
	In-Situ Treatment				•			•	
	Excavation/Treatment					•			•
	Residuals Management								
	Containment			•	•	•			
	In-Situ Treatment						•	•	
	Excavation/Treatment								•

Note:
The preliminary assembly of remedial alternatives is based upon the preliminary screening of candidate technologies (Table 7) and the considerations outlined in Section 4.4 of this Work Plan.

Table 9. Justification and Boring Depths for Proposed Soil and Sediment Sampling Locations. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Activity Number and Description	Boring Number	Proposed Depth Interval (Ft. BGS)	Justification
2b - Former Lagoon Area	L-1, L-2, L-7, L-8 L-3 through L-6	60 100	Evaluate the stratigraphy of the lagoon area, including the presence of a confining and/or peat layer and the distribution and characteristics of chemical residuals, below the former lagoon, remaining after initial remedial activities, including screening for DNAPL.
	L-9A through L-16B	40	Evaluate the stratigraphy of the soils surrounding the lagoon, including the presence of a confining and/or peat layer and the distribution and characteristics of chemical residuals remaining around the former lagoon after initial remedial activities, including screening for DNAPL.
2b - Former Process Area	P-20	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the west of the lagoon. Gives coverage between proposed borings L-15B and L-16B.
	P-21	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the west of the lagoon. Evaluate the extent of product encountered in USEPA borings B-1 and B-2.
	P-22	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs which were not analyzed in nearby USEPA boring SB-18, which had elevated concentrations of BTEX.
	P-23	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs and the extent of product encountered in USEPA boring B-1 and B-2.
	P-24	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs, which were not analyzed in nearby USEPA boring B-7, which had elevated concentrations of BTEX, and the extent of product encountered in USEPA boring B-33.
	P-25	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs and the extent of product encountered in USEPA boring B-6.
	P-26	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings were not previously installed.
	P-27	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs and the extent of product encountered in USEPA boring B-32.
	P-28	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs.
	P-29	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings were not previously installed.
	P-30	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the Former Process and Tank Areas and extent of product encountered in the drainage ditch (MW-13A).
	P-31	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the Former Process and Tank Areas and the extent of product encountered in the drainage ditch (MW-13A).
	P-32	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs which were not analyzed in nearby USEPA boring SB-19, which had elevated BTEX concentration.
	P-33	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the Former Process and Tank Areas and the extent of product encountered in the drainage ditch (MW-13A).
	P-34	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs.
	P-35	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the Former Process and Tank Areas and the extent of product encountered in the drainage ditch (MW-13A).
	P-36	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs which were not analyzed in nearby USEPA boring S45Y-1, which had elevated BTEX concentrations.
	P-37	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs.
	P-38	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings were not previously installed.
	P-39	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings will be continued six inches into the first inorganic layer.

Table 9. Justification and Boring Depths for Proposed Soil and Sediment Sampling Locations. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Activity Number and Description	Boring Number	Proposed Depth Interval (Ft. BGS)	Justification
	P-40	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings were not previously installed.
	P-41	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings were not previously installed.
	P-42	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs in an area where soil borings were not previously installed.
	P-43	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs and the extent of product encountered in USEPA boring B-27.
	P-44	40	Evaluate the stratigraphy (clay/peat) and COPC concentrations to the north of the lagoon including chlorinated VOCs and the extent of product encountered in USEPA boring B-30 and B35MM-1.
	PB-1 through PB-5	10	Evaluate concentrations of COPCs in soil and the presence of NAPL in the vicinity of the Pepper Building.
4a - Monitoring Well Installation	MW-24S, MW-25S, MW-28S, MW-29S, MW-30S, MW-31S, MW-32S	15	Evaluate the stratigraphy of the Cape May Formation and the Upper PRM and determine if NAPL is present below table water.
	PZ-1 AND PZ-2	10	Evaluate the stratigraphy of the soils below the base of Gaventa and Swindell Pond; evaluate the geotechnical properties of the soil and to determine if a clay layer is present below the water bodies.
	MW-4D, MW-18D, MW-20D through MW-23D, MW-26D, MW-27D	60-160	Evaluate the stratigraphy of the Upper and Middle PRM and to determine if confining layers are present between the Upper and Middle PRM and between the Upper-Middle and Lower-Middle PRM.
5a - Gaventa and Swindell Ponds	GVT-1 through GVT-8	0.5	Evaluate the distribution and gradients of COPCs in the sediments of Gaventa Pond.
	SWD-1 through SWD-3	0.5	Evaluate the distribution and gradients of COPCs in the sediment in Swindell Pond.
5b - Little Timber Creek and Swamp	LTC-1 through LTC 61	TBD[1]	Characterize the de manifestis, intermediate and de minimis zone boundaries; establish gradients of COPCs, characterize the distribution of NAPL in the de manifestis zones, characterize the physical and chemical properties of the wetlands.
	R-1 through R-15	TBD[1]	Reference area samples to establish background concentrations of COPCs and to support the ecological risk assessments.

[1]The soil borings will be continued six inches into the first inorganic layer.

Table 10. Analytical Parameters for Soil and Sediment Samples. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Activity # and Description	Boring Designation	Total Depth of Boring (ft BGS)	Laboratory Sample Collection Targets	Sampling Interval Per Boring	Samples per Boring for Laboratory Analysis	TCL Volatile Organic Compounds	TCL Semivolatile Organic Compounds	Polychlorinated Biphenyls	TAL Metals	Total Organic Carbon	Total Petroleum Hydrocarbons[11]	Lead[11]	Eh	pH	Diesel Range Organics/Gasoline Range Organics	Total Petroleum Hydrocarbons	Geotechnical[1]	Grain Size	Waste Classification[2]	Volatile Acid Sulfide	Cation Exchange Capacity	Micro Organism Identification	SPLP for VOCs and Metals
2b - Former Lagoon Area	L-1, L-2, L-7, L-8	60	LR, NAPL	Continuous	4[13]	✓[10]	✓	✓	✓	✓[3]			✓[3]	✓[3]		✓	4[1]		1				✓[15]
	L-3 through L-6, MW-26D and MW-27D	100	LR, NAPL	Continuous	8	✓[10]	✓	✓	✓	✓[3]			✓[3]	✓[3]		✓	4[1]						✓[15]
	L-9A through L-16B	40	LR, NAPL	Continuous	4	✓[10] ✓[10]	✓	✓	✓	✓			✓	✓	✓	✓	2[1]		4				✓[15]
2b - Former Process Area	P-20 through P-44	40	LR, NAPL	Continuous	3[13]	✓[10]	✓	✓	✓	✓			✓	✓		✓	8[1]		4				
	PB-1 through PB-5	10[4]	LR, NAPL	Continuous	3	✓[10]	✓	✓	✓	✓			✓	✓		✓							
3 - NAPL Delineation	TBD	TBD	NAPL	Continuous	1	✓				✓						✓							✓[15]
4a - Monitoring Well Installation	MW-24S, MW-25S, MW-28S through MW-32S	15	DLN	Continuous	2	✓[10]	✓	✓	✓								3[1]						
	PZ-1, PZ-2	10[5]	DLN	Continuous	2	✓[10] ✓[10]	✓	✓	✓								✓						
	MW-4D, MW-18D, MW-20D through MW-23D, MW-26D, MW-27D	90-160	DLN	Continuous	5[14]	✓[10]	✓	✓	✓								✓[1]						
5a - Gaventa and Swindell Ponds	GVT-1 through GVT-8	0.5[6]	DLN	Continuous	1	✓	✓	✓	✓	✓			✓	✓				✓		✓	✓		
	SWD-1 through SWD-3	0.5[6]	DLN	Continuous	1				✓[9]	✓			✓	✓				✓		✓	✓		
5b - Little Timber Creek and Swamp	LTC-5, LTC-7 through LTC-11, LTC-50	TBD[6]	2nd DLN	Continuous	10+						✓	✓											
	LTC-1 through LTC-4, LTC-6, LTC-12	TBD[6]	2nd DLN	Continuous	2						✓	✓											
	through LTC-49, LTC-51 through LTC-TBD[7]	TBD[7]	2nd DLN	Continuous	3[12]	✓	✓	✓	✓	✓			✓	✓		✓		✓	4	30%	30%	✓	9[8]
	Background Samples (R-1 through R-15)	TBD[7]	Background	Continuous	2[7]	✓	✓	✓	✓	✓			✓	✓		✓		✓		33%	33%		

✓ = All samples to be analyzed unless otherwise noted.
LR = Lagoon residuals or process area delineation/characterization.
NAPL = NAPL delineation/characterization.
DLN = General delineation/screening.
2nd DLN = Secondary source delineation (overflow area).
TBD = To be determined.
ECO/BD = Ecological Evaluation/Biodegradation.

(1) Geotechnical parameters include: permeability, porosity, water content, specific gravity, plastic limits, and grain size. Shelby tubes will be collected from the following boring: P-20, P-23, P-26, P-28, P-31, P-36, P-41, P-43, L-1, L-2, L-4 L-8, L-10A, L-12A, one from the lagoon backfill, MW-24S, MW-25S, MW-31S, plus the anticipated screened internal for all Upper Middle PRM monitoring wells installed, except the wells which will be installed through slotted augers.
(2) Waste classification parameters include: TCLP volatile organic compounds, semivolatile organic compounds, metals, and pesticides/herbicides, plus total polychlorinated biphenyls, ignitability, corrosivity, total organic halides and BTU content.
(3) Five samples each of the ash and fill emplaced into the former lagoon, in addition to the samples collected from the lagoon residual.
(4) The borings will be completed to a depth of two feet below the water table.
(5) Sediment samples from Gaventa and Swindell Ponds will be collected from the 0- to 6-inch interval below the base of the pond floor.
(6) Sediment samples from the de manifestis zone (LTC-5, LTC-7 through LTC-11, and LTC-50) will be collected from six-inch intervals to a depth of 5 feet unless NAPL is encountered or screening results are at concentrations greater than 1,000 mg/kg TPH or 500 mg/kg lead. Samples will continue to be collected at six-inch intervals to one foot below the evidence of NAPL. Samples in the intermediate and de minimus zones will be collected from 0-6 inches from the sediment and 0-6 inches in the first inorganic substratum.
(7) For the second round or confirmitory round, sediment samples will be collected from the 0- to 1-inch and 0 to 6 inch interval below the surface. The sediment/soil samples will be collected from the 0- to 6-inch interval in the first inorganic layer.
(8) Sediment/soil samples collected are LTC-7, LTC-8, LTC-14, LTC-16, LTC-25, LTC-37, LTC-44, LTC-45, LTC-50.
(9) Analysis of arsenic, chromium, copper, lead and zinc only.
(10) Soil samples will be preserved with methanol; however, a percentage of soil samples will be collected without methanol preservation for comparability analysis.
(11) Compound to be analyzed using a on-site laboratory.
(12) Additional samples to be analyzed for TCL - volatile organic compounds, TCL-semivolatile organic compounds, polychlorinated biphenyls, TAL metals and total organic carbon based on field screening results.
(13) Surface soil samples (0-1") from borings L-4, P-26, P-34 and a third location from the former Process Area to be selected in the field in addition to the number of samples per boring listed.
(14) Background soil samples will be collected from 2 depths, (0-6" and 18-24"), from six off-property locations: MW-17D, MW-18D, MW-19D, MW-20D, MW-33D and MW-34D.
(15) SPLP analysis for VOCs and metals from 12 samples within the former lagoon Area and 9 samples from NAPL saturated soil. Borings and depth intervals to be determined in the field.

Table 11. Justification and Screened Intervals for Proposed Monitoring Wells. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Well No.	Proposed Screen Interval (ft BGS)	Aquifer	Justification
MW-4D	105-115	Base of Upper Middle PRM	Determine presence/absence of DNAPL; Determine COPCs at base of Upper Middle PRM; Flux calculations
MW-17D through MW-19D and MW-33D and MW-34D	150-160	Base of Upper Middle PRM	Delineation of COPCs south of Route 295
MW-20D	80-90	Base of Upper Middle PRM	Evaluate western extent of VOCs; Determine upgradient conditions for model calibration
MW-21S	5-15	Upper PRM	Delineation of VOC gradient between Route 130 and Route 295; Evaluate horizontal contaminant gradient away from former lagoon; Evaluate vertical gradients beneath wetlands; Calibrate flow model; Key monitoring wells for pumping test; Obtain geochemical data
MW-21L	30-40	Base of Upper PRM	
MW-21I	50-60	Top of Upper Middle PRM	
MW-21D	120-130	Base of Upper Middle PRM	
MW-22S	5-15	Upper PRM	Delineation of VOC gradient between Route 130 and Route 295; Evaluate horizontal contaminant gradient away from former lagoon; Evaluate vertical gradients beneath wetlands; Calibrate flow model; Key monitoring wells for pumping test; Obtain geochemical data
MW-22L	30-40	Base of Upper PRM	
MW-22I	50-60	Top of Upper Middle PRM	
MW-22D	110-120	Base of Upper Middle PRM	
MW-23S	5-15	Upper PRM	Characterize surface-water/ground-water relationship between Swindell Pond and aquifer; Calibrate model; Flux calculations
MW-23I	40-50	Top of Upper Middle PRM	
MW-23D	95-105	Base of Upper Middle PRM	
MW-24S	5-15	Upper PRM	Evaluate LNAPL south of Pepper Building
MW-25S	5-15	Upper PRM	Evaluate LNAPL in swale north of former tank farm
MW-26S	20-30	Upper PRM	Evaluate ground-water conditions within and below former lagoon; Determine continuity of clay layer immediately underlying lagoon; Determine presence/absence of LNAPL; Determine presence/absence of DNAPL; Calibrate model; Flux calculations
MW-26I	45-55	Top of Upper Middle PRM	
MW-26D	90-100	Base of Upper Middle PRM	
MW-27S	20-30	Upper PRM	Evaluate ground-water conditions within and below former lagoon; Determine continuity of clay layer immediately underlying lagoon; Determine presence/absence of LNAPL; Determine presence/absence of DNAPL; Calibrate model; Flux calculations
MW-27I	45-55	Top of Upper Middle PRM	
MW-27D	90-100	Base of Upper Middle PRM	

Table 11. Justification and Screened Intervals for Proposed Monitoring Wells. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Well No.	Proposed Screen Interval (ft BGS)	Aquifer	Justification
MW-28S	5-15	Upper PRM	Determine if Pepper Building area is source of COPCs in ground-water contamination detected north of Route 130
MW-29S	5-15	Upper PRM	Evaluate LNAPL between former process area and wells MW-1A and S11A
MW-30S through MW-32S	5-15	Upper PRM	Delineate potential LNAPL in former process area; Evaluate ground-water quality in former process area
PZ-1	20-30	Upper PRM[1]	Characterize surface-water/ground-water relationship between Gaventa Pond and former lagoon; Calibrate model; Flux calculations
PZ-2	20-30	Upper PRM[1]	Characterize surface-water/ground-water relationship between Swindell Pond and aquifer; Calibrate model; Flux calculations
WMW-1 through WMW-6	1-3/4-6[2]	Upper PRM	Evaluate vertical flow gradients in Little Timber Creek Swamp; Determine ground-water quality with depth; Supplement water budget data

Notes:

[1]If there is no appreciable thickness of the Upper PRM below the base of the ponds then the well screens will be located to monitor the confining layer and/or the top of the Upper Middle PRM aquifer.

[2]A pair of monitoring wells constructed by alternative methods; one screened from 1-3 ft BGS and one screened from 4-6 ft BGS.

VOC = Volatile organic compounds
DNAPL = Dense non-aqueous phase liquids
LNAPL = Light non-aqueous phase liquids
ft BGS = Feet below ground surface
COPCs = Constituents of potential concern

Table 12. Summary of Proposed Monitoring Well Construction Details. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Well Designation	Formation Screened	Depth of Well (ft BGS)	Well Diameter (inches)	Screened Interval (ft BGS)	Well Screen Material	Well Casing Material	Filter Pack Size	Drilling Method
MW-4D	BUMPRM	115	2	105 - 115	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-17D	BUMPRM	160	2	150 - 160	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-18D	BUMPRM	160	2	150 - 160	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-19D	BUMPRM	160	2	150 - 160	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-20D	BUMPRM	90	2	80 - 90	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-21S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-21L	BUPRM	40	2	30 - 40	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-21I	TUMPRM	60	2	50 - 60	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-21D	BUMPRM	130	2	120 - 130	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-22S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-22L	BUPRM	40	2	30 - 40	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-22I	TUMPRM	60	2	50 - 60	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-22D	BUMPRM	120	2	110 - 120	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-23S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-23I	TUMPRM	40	2	30 - 40	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-23D	BUMPRM	105	2	95 - 105	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-24S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-25S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-26S	UPRM	30	2	20 - 30	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-26I	TUMPRM	55	2	45 - 55	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-26D	BUMPRM	100	2	90 - 100	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-27S	UPRM	30	2	20 - 30	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-27I	TUMPRM	55	2	45 - 55	SS - 20 Slot	SS - Type 304	Morie 1	MR
MS-27D	BUPRM	100	2	90 - 100	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-28S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-29S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-30S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-31S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-32S	UPRM	15	2	5 - 15	SS - 20 Slot	SS - Type 304	Morie 1	HSA
MW-33D	BUMPRM	160	2	150 - 160	SS - 20 Slot	SS - Type 304	Morie 1	MR
MW-34D	BUMPRM	160	2	150 - 160	SS - 20 Slot	SS - Type 304	Morie 1	MR
PZ-1	UPRM[1]	30	2	20 - 30	SS - 20 Slot	SS - Type 304	Morie 1	PONTOON
PZ-2	UPRM[1]	30	2	20 - 30	SS - 20 Slot	SS - Type 304	Morie 1	PONTOON
WMW-1	UPRM[1]	6	2	1-3/4-6[2]	SS - 10 Slot	SS - Type 304	Morie 0	HA
WMW-2	UPRM[1]	6	2	1-3/4-6[2]	SS - 10 Slot	SS - Type 304	Morie 0	HA
WMW-3	UPRM[1]	6	2	1-3/4-6[2]	SS - 10 Slot	SS - Type 304	Morie 0	HA
WMW-4	UPRM[1]	6	2	1-3/4-6[2]	SS - 10 Slot	SS - Type 304	Morie 0	HA
WMW-5	UPRM[1]	6	2	1-3/4-6[2]	SS - 10 Slot	SS - Type 304	Morie 0	HA
WMW-6	UPRM[1]	6	2	1-3/4-6[2]	SS - 10 Slot	SS - Type 304	Morie 0	HA

NOTES:

Ft BGS = Feet below ground surface.
UPRM = Upper Potomac Raritan Magothy.
BUPRM = Base of Upper Potomac Raritan Magothy.
TUMPRM = Top of Upper Middle Potomac Raritan Magothy.
BUMPRM = Base of Upper Middle Potomac Raritan Magothy.
SS = Stainless Steel.
HSA = Hollow-Stem Auger.
HA = Hand Auger.
MR = Mud Rotary.
PZ = Piezometer.
MW = Monitoring Well.

[1] If there is no appreciable thickness of the Upper PRM below the base of the ponds then the well screens will be located to monitor the top of the Upper M PRM aquifer.

[2] Consists of Pair of Monitoring wells constructed by alternative methods, screened from 1-3 ft BGS and one screened from 4-6 ft BGS.

Table 13. Analytical Parameters for Ground Water and Surface Water. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Activity # and Description	Sample Designation	Number of Sampling Points	TCL Volatile Organic Compounds	TCL Semivolatile Organic Compounds	TCL Base Neutrals	Polychlorinated Biphenyls	Total Petroleum Hydrocarbons	TAL Metals	Alkalinity	Total Suspended Solids	Total Dissolved Solids	Sulfate/Sulfide	Nitrate/Nitrite/Ammonia	Chloride	Silica	Orthophosphate	Chemical Oxygen Demand	Total Kjeldahl Nitrogen	Total Organic Carbon	Dissolved Oxygen*	Hardness	Eh/pH/specific conductance/temperature*	Ferrous Iron*	Methane, Ethene, Ethane	Organic Acids	Waste Classification[1]	Carbon Dioxide	Hydrogen Sulfide	Dissolved Iron
1b - Evaluation of Ground Water Use On and Around the Site	To be determined																												
4a - Ground-Water Quality Evaluation	MW-170 through MW-19D, MW-33D, MW-34D	5	✓[10]																										
	MW-170 through MW-19D, MW-33D, MW-34D	5	✓																										
	First round [2]	42	✓[9]	✓				✓[5]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Second round [3]	56	✓[9]		✓			✓[5]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
	Third round [4]	20	✓[9]																	✓		✓	✓						
	Fourth round [4]	20	✓[9]																	✓		✓	✓						
5b - Little Timber Creek Surface Water Quality Evaluation	LTC-1 through LTC-6 LTC-12 through LTC-13 LTC-51 through LTC-55 LTC-58 through LTC-61	22	✓	✓[6]		✓[6]	✓	✓[6]	✓	✓[7]	✓[7]	✓[7]	✓[7]	✓[7]				✓[7]	✓[6]		✓[7]	✓	✓[7]						
Background/Reference Wetland Surface Water Quality Evaluation	R-2, R-5, R-3, R-4	4	✓	✓[6]		✓[6]	✓	✓[6]	✓	✓[7]	✓[7]	✓[7]	✓[7]	✓[7]				✓[7]	✓[6]		✓[7]	✓	✓[7]						
5a - Gaventa and Swindell Pond Surface Water Quality Evaluation	GVT-1 through GVT-3	3		✓			✓	✓	✓	✓	✓								✓	✓	✓	✓	✓						
	SWD-1 through SWD-3	3		✓			✓	✓	✓	✓	✓								✓	✓	✓	✓	✓						
5c - Swale along Route 130	SWL-1 and SWL-2	2	✓	✓[6]		✓[6]	✓[6]	✓[6]																					

* = Measured in the field.

[1] Analysis of investigation derived wastes for the following parameters for waste disposal classification: Volatile organic compounds, semivolatile organic compounds, metals, pesticides/herbicides, total polychlorinated biphenyls, ignitability. corrosivity and reactivity.

[2] First round monitoring wells = All existing MW designated wells (30 wells) plus S-1A, S-1B, S-1C, S-2A, S-2C, S-3A, S-3C, S-4, S-6, S-11A, S-11C, EPA-107 and EPA-108.

[3] Second round monitoring wells =MW-1A, S-2C, S-3C, MW-5B, MW-7A, MW-8A, MW-8B, MW-10B, S-11A, MW-11B, MW-11C, MW-13-A, and MW-14B plus all new monitoring wells.

[4] Third and fourth round monitoring wells = MW-1A, S-2C, S-3C, MW-5B, MW-7A, MW-8A, MW-8B, MW-10B, S-11A, MW-11B, MW-11C, MW-13A, MW-14B, MW-18D, MW-20D, MW-21D, MW-22D, MW-23D, MW-24S, MW-25S, MW-33D and MW-34D plus intermediate depth wells to be determined based on second round results.

[5] Monitoring wells MW-26S, MW-26I, MW-26D, MW-27S, MW-27I, MW-27D, MW-29S, MW-1A, and S-11A to be analyzed for dissolved metals, as appropriate.

[6] Also analysis of dissolved constituents.

[7] 50 percent of the samples collected will be analyzed for this parameter.

[8] Total organic carbon samples will be field filtered to approximate dissolved organic carbon.

[9] All monitoring wells samples will be collected using the low flow sampling methods; however, a percentage of monitoring well samples will be collected using conventional purge and sampling methods for comparability analysis. First round: SC-11C, MW-5B, MW-7A, MW-8A, MW-8B, MW-10B, MW-11B, MW-14B. Second and third rounds: MW-18D, MW20D, MW21D, MW-22D, MW23D, MW24S, MW-25S, MW-29S, MW-33D, MW-34D. Subsequent rounds: 30% of the wells or 10 of the wells listed for the second and third rounds, whichever is less, if needed based upon to results of the prior rounds.

[10] Ground water grab samples will be collected through the slotted augers at 20 foot intervals and analyzed for VOCs using a field laboratory.

[11] TCL VOCs by EPA method 500 series.

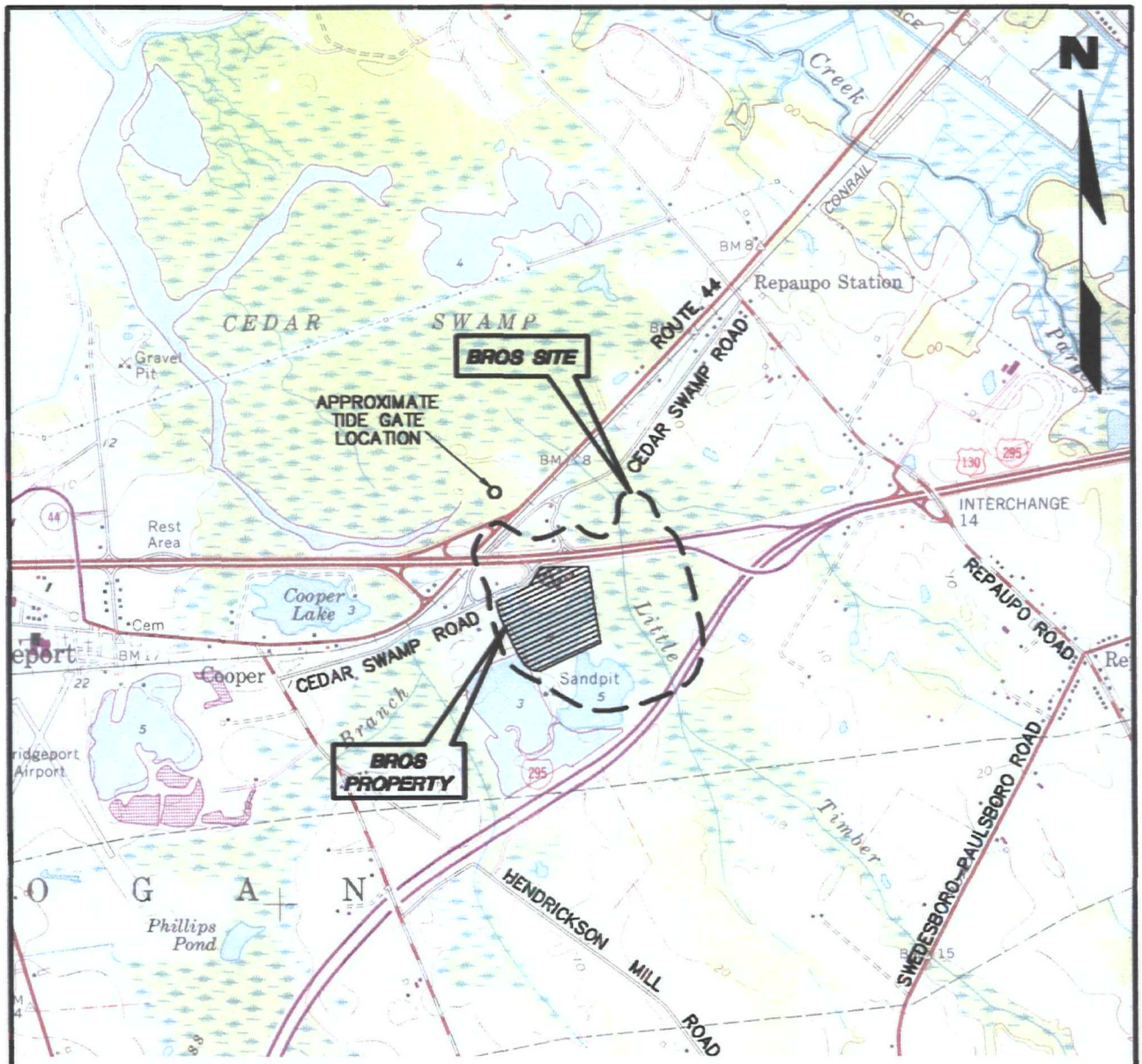
Table 14. Analysis of Potential Exposure Pathways for the Trespassing Exposure Scenario. BROS Phase 2 RI/FS; Bridgeport, New Jersey.

Provided as an Example Table Only - Information Shown in this Table is NOT Meant to be Representative of Any Conditions at the BROS Site

Receiving Media/ Release Mechanism	Receptor	Exposure Route	Pathway to be Evaluated[1]	Reason for Inclusion or Exclusion	Reference to Conceptual Model
Ambient Air					
Fugitive dust/wind erosion from surface soil and onsite sediments	Adult	Inhalation	Yes	Surface soils and sediments may be exposed/disturbed resulting in dust generation.	3b
Volatilization from surface soil[2]	Adult	Inhalation	Yes	Chemicals may volatilize from surface soils and sediments at Site.	3b
Volatilization from subsurface soil[3]	Adult	Inhalation	No	Subsurface soils are assumed to not be routinely disturbed, thus, receptors other than construction workers are unlikely to be exposed.	3b
Volatilization from surface water	Adult	Inhalation	No	No permanent body of water exists - only puddles from recent rain events occur on an intermittent basis.	19b
Onsite Soils and Sediments					
Surface soils[2] - direct contact	Adult	Incidental ingestion Dermal absorption	Yes Yes	Direct contact with soils and sediments may occur while playing onsite.	9a 9c
Subsurface soils[3] - direct contact	Adult	Incidental ingestion Dermal absorption	No No	Subsurface soils are assumed to not be disturbed/contacted during visits to the Site.	9a 9c
Surface Water					
Direct contact	Adult	Incidental ingestion Dermal absorption	No No	No permanent body of water exists - only puddles from recent rain events occur on an intermittent basis.	19a 19c
Ground Water					
Direct contact	Adult	Ingestion Inhalation Dermal absorption	No No No	Incomplete pathway: ground water is not utilized for any purpose at the Site.	31a 31b 31c

[1] If constituents of interest are present in receiving media.
[2] Surface soils are defined as 0 to 1 foot interval and sediments from the drainage swale.
[3] Subsurface soils are defined as 1 to 6 foot interval.

FIGURES



QUADRANGLE LOCATION

2,000' 0' 2,000'

LEGEND

- APPROXIMATE SITE BOUNDARY
- APPROXIMATE PROPERTY BOUNDARY

SOURCE:

U.S.G.S. BRIDGEPORT, N.J., QUADRANGLE 1967
7.5 MINUTE SERIES (TOPOGRAPHIC)
PHOTOREVISED 1986
CONTOUR INTERVAL 10 FEET

Title:

SITE LOCATION MAP SHOWING THE APPROXIMATE BROS PROPERTY AND BROS SITE BOUNDARIES

BRIDGEPORT RENTAL & OIL SERVICES SITE LOGAN TOWNSHIP, NEW JERSEY

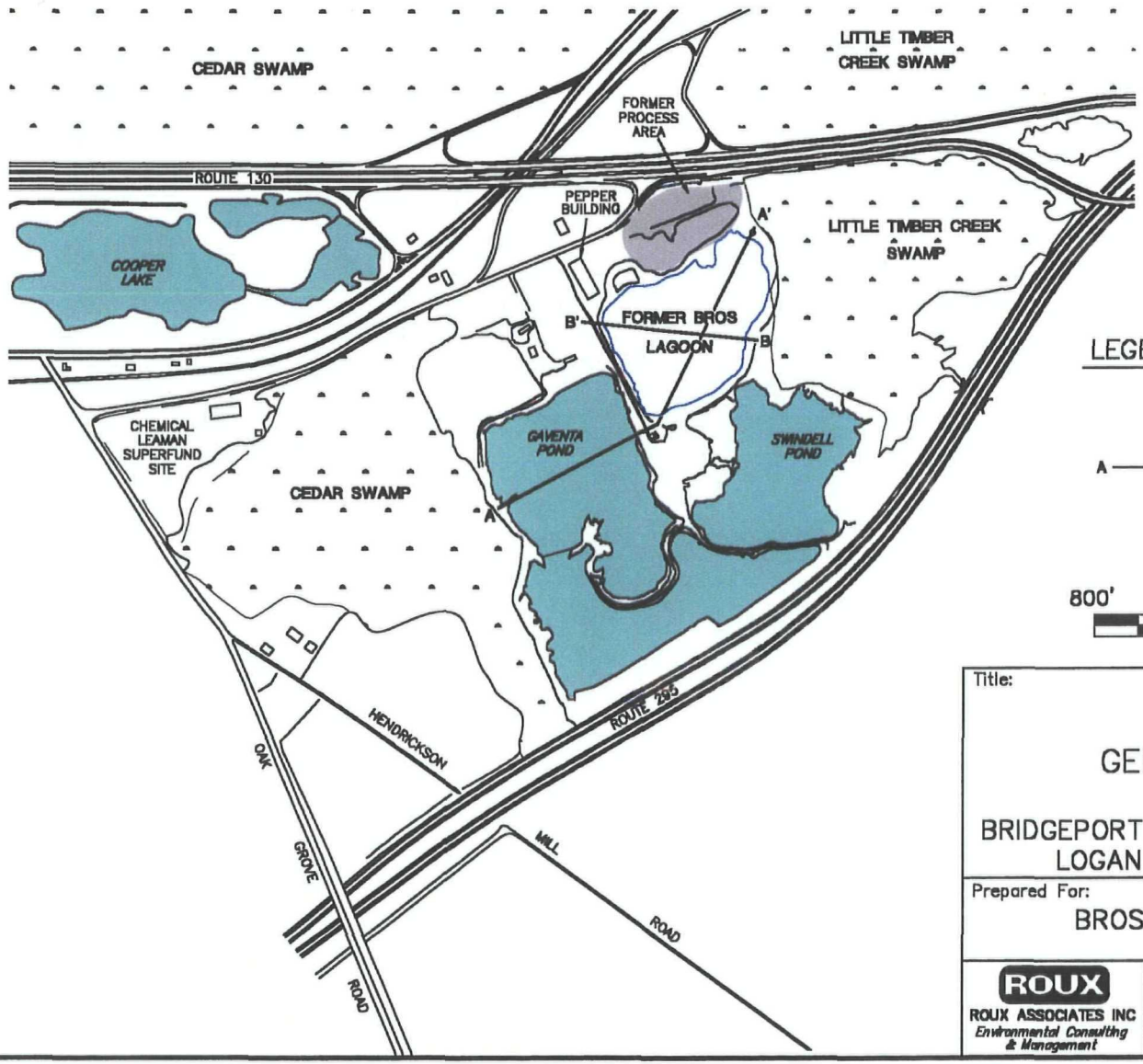
Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 06/30/98	Figure
Prepared by: J.R.M.	Scale: SHOWN	1
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301017	

300851



N

LEGEND

WETLANDS

A ——— A' LINE OF CROSS SECTION

800' 0' 800'

Title:

GENERAL SITE PLAN

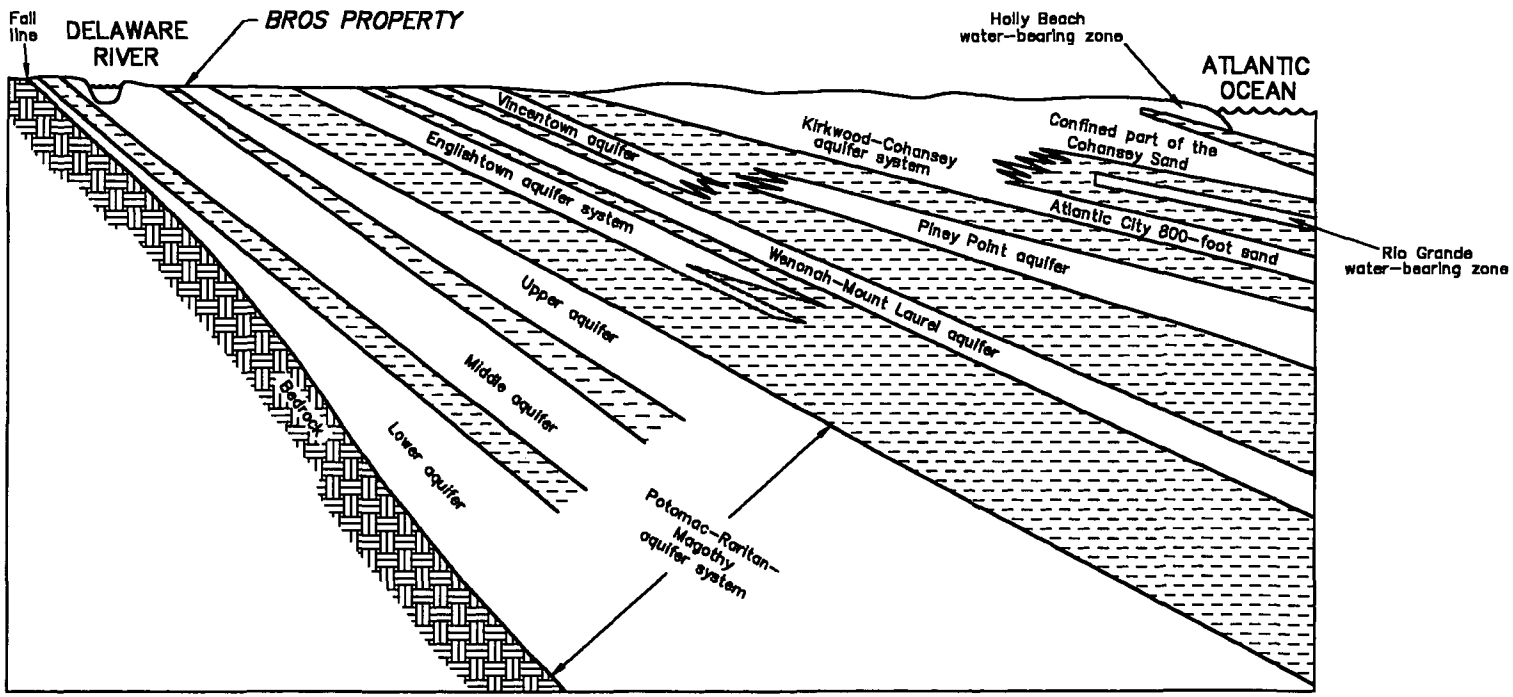
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 06/30/98	Figure 2
	Prepared by: J.R.M.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301023	

300852



LEGEND

CONFINING UNIT

REFERENCE:

MODIFIED FROM NJDEP, 1988,"WATER LEVELS IN MAJOR ARTESIAN AQUIFERS OF THE NEW JERSEY COASTAL PLAIN."

Title:

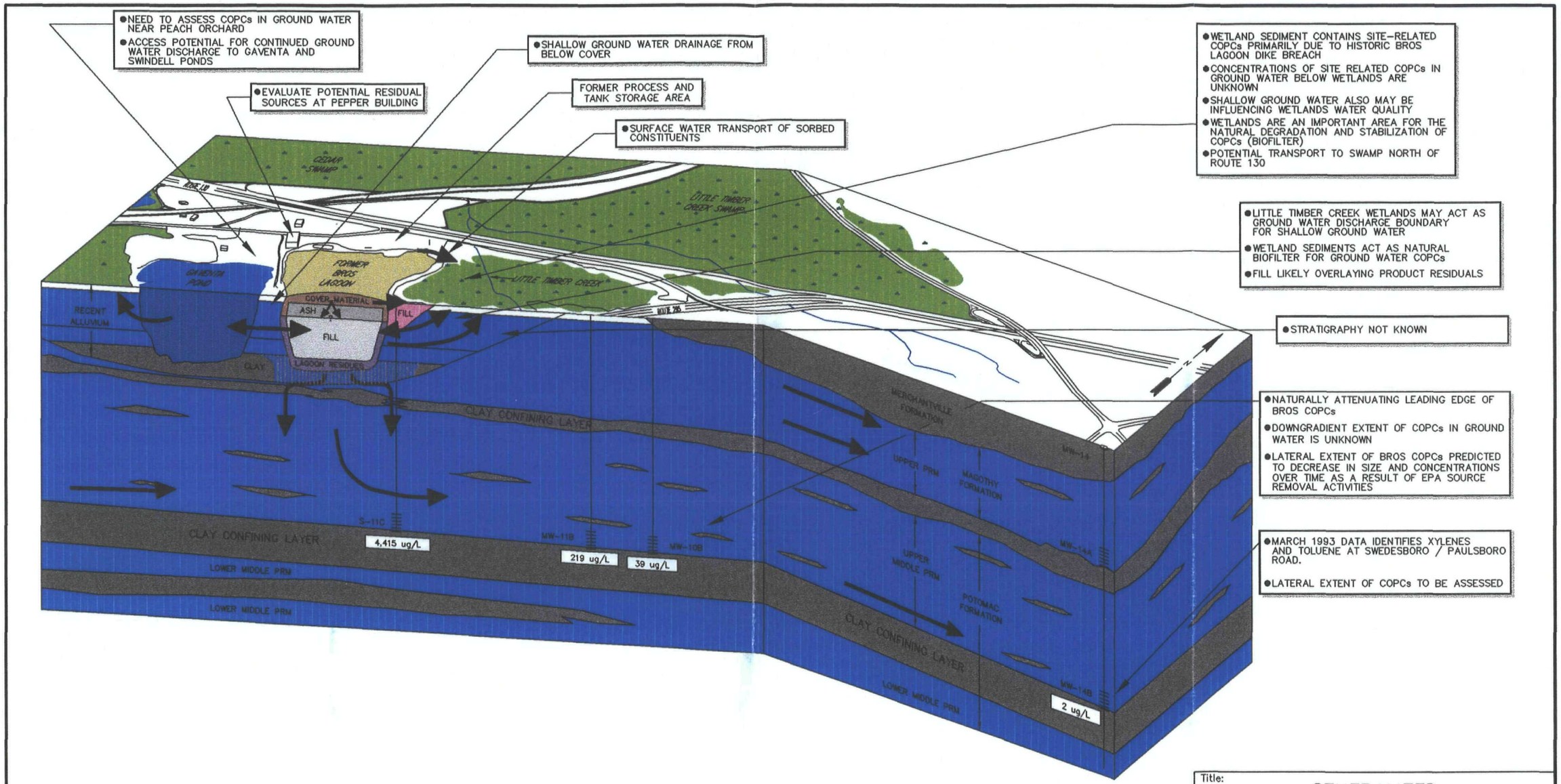
DIAGRAMMATIC HYDROGEOLOGIC SECTION OF THE NEW JERSEY COASTAL PLAIN
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 06/30/98	Figure 3
	Prepared by: J.R.M.	Scale: N.T.S.	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301025	

300853



NOTE

GROUND WATER FLOW ARROWS REPRESENT FLOW DIRECTIONS PRIOR TO CONCLUSION OF LAGOON WORK

39 ug/L — TOTAL VOC CONCENTRATION, SEPTEMBER 1990 (EXCEPT MW-14B FROM MARCH 1993)

Title:

GENERALIZED CONCEPTUAL COPC TRANSPORT MODEL

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 06/30/98	Figure
Prepared by: J.S.G.	Scale: N.T.S.	4
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301079	

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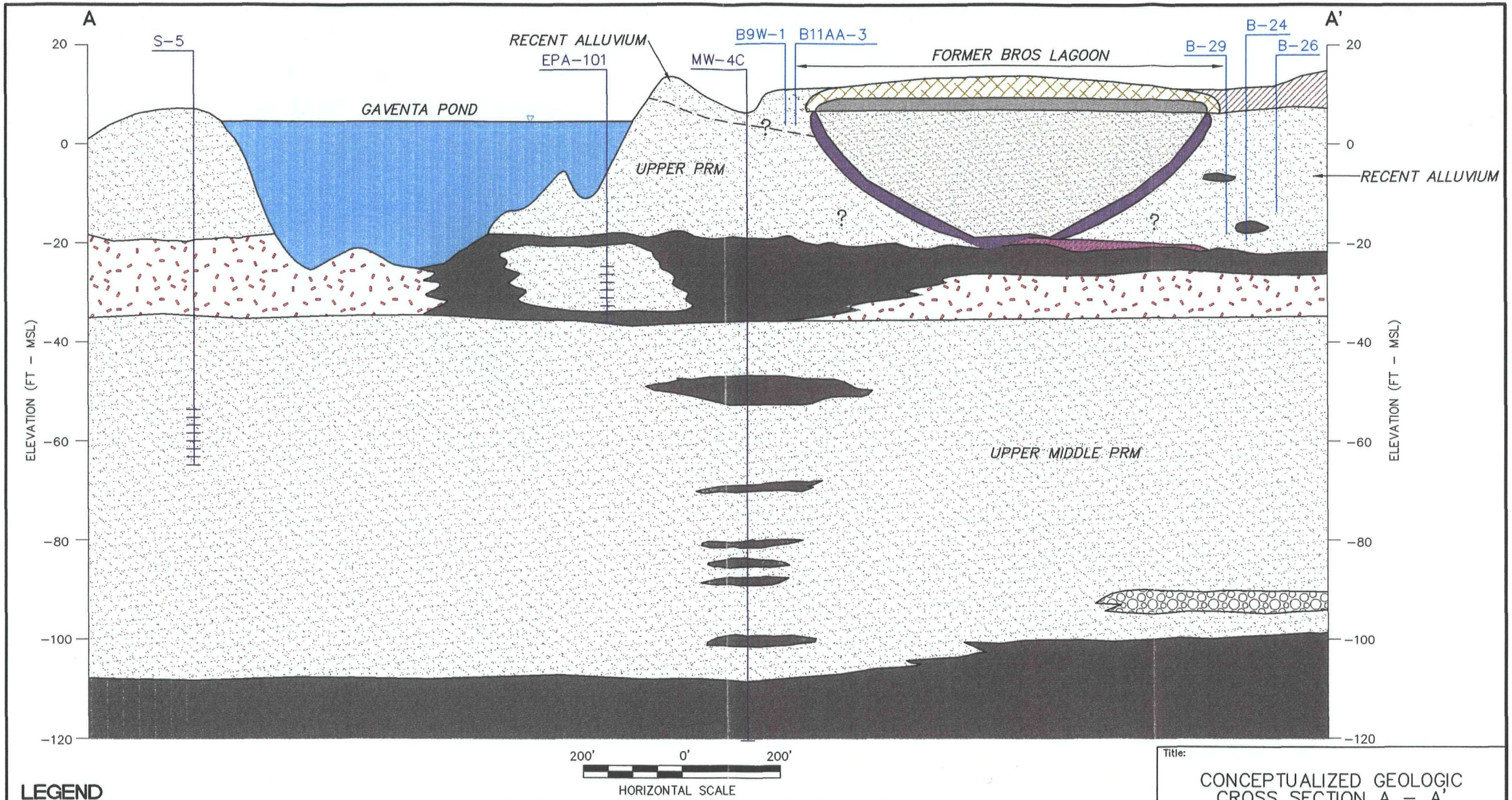

LEGEND

EPA-101 MONITORING WELL IDENTIFICATION AND LOCATION

B-24 SOIL BORING IDENTIFICATION AND LOCATION

NATIVE SAND

SILT

CLAY

GRAVEL

COVER MATERIAL

SAND BACKFILL

FILL

PEAT

ASH

LAGOON RESIDUALS

? DISTRIBUTION OF COPCs IN PEAT IS UNKNOWN EXTENT OF PEAT UNDER FORMER LAGOON IS UNKNOWN

Title:

CONCEPTUALIZED GEOLOGIC CROSS SECTION A – A'

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: J.L.	Date: 06/30/98	Figure	
Prepared by: M.M.H.	Scale: SHOWN	5	
Project Mgr: N.R.	Revision:		
Proj No: 49301J05	File No: 49301094		

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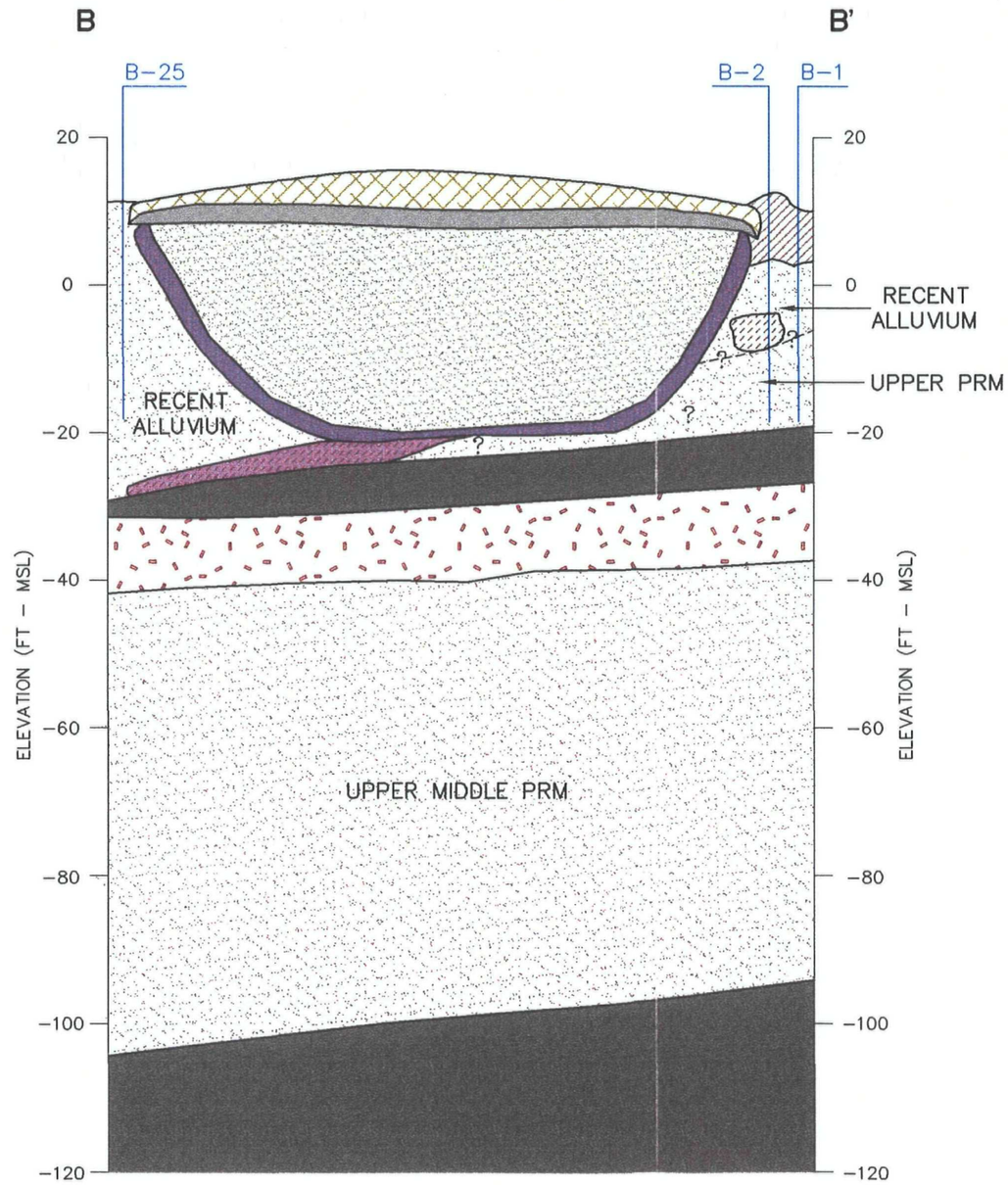

LEGEND

B-15 — SOIL BORING IDENTIFICATION AND LOCATION

- NATIVE SAND
- SILT
- CLAY
- GRAVEL
- COVER MATERIAL
- ASH
- LAGOON RESIDUALS
- SAND BACKFILL
- FILL
- PEAT

? — DISTRIBUTION OF COPCs IN PEAT IS UNKNOWN EXTENT OF PEAT UNDER FORMER LAGOON IS UNKNOWN

200' 0' 200'

HORIZONTAL SCALE

Title:

CONCEPTUALIZED GEOLOGIC CROSS SECTION B – B'

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: J.L.	Date: 06/30/98	Figure
Prepared by: J.S.G.	Scale: SHOWN	6
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301093	

300856

LEGEND

MW-10A MONITORING WELL LOCATION AND IDENTIFICATION

NOTES

1.) MONITORING WELL LOCATIONS ARE ESTIMATED BASED ON A CH2M HILL FIGURE ENTITLED, "MONITORING WELL LOCATION MAP".

Title:

EXISTING MONITORING WELL LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC *Environmental Consulting & Management*	Compiled by: B.G.	Date: 07/06/98	Figure 7
	Prepared by: J.R.M.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301078	

300857

LEGEND

- B-10 — LOCATION AND DESIGNATION OF EXISTING BOREHOLE
- MW-2 — LOCATION AND DESIGNATION OF EXISTING MONITORING WELL
- LOCATION OF FENCE
- GATE
- APPROXIMATE LIMITS OF FORMER LAGOON
- POTENTIAL LNAPL LOCATIONS

NOTES

1.) LNAPL AREA NORTH OF ROUTE 130 HAS NOT BEEN DEPICTED.

2.) DRAWING ADAPTED FROM U.S. ARMY ENGINEER, DISTRICT PHILADELPHIA, CORPS OF ENGINEERS, PHILADELPHIA, PENNSYLVANIA.

3.) MONITORING WELL LOCATIONS ARE ESTIMATED BASED ON A CH2M HILL FIGURE TITLED MONITOR WELL LOCATION MAP.

APPROXIMATE SCALE

130' 0' 130'

Title:

POTENTIAL LNAPL LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 06/30/98	Figure
Prepared by: J.S.G.	Scale: SHOWN	8
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301103	

300858

LEGEND

B-10 ●	LOCATION AND DESIGNATION OF WINTER 1996/1997 USEPA BORING
5 ○	LOCATION AND DESIGNATION OF 1990/1993 CH2M HILL SURFACE SOIL SAMPLE
MW-2 ⊕	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL
—×—×—×—	LOCATION OF FENCE
	GATE
	APPROXIMATE LIMITS OF FORMER LAGOON

NOTES

1.) DRAWING ADAPTED FROM U.S. ARMY ENGINEER, DISTRICT PHILADELPHIA, CORPS OF ENGINEERS, PHILADELPHIA, PENNSYLVANIA.

2.) MONITORING WELL LOCATIONS ARE ESTIMINATED BASED A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

APPROXIMATE SCALE

130' 0' 130'

Title:

PREVIOUS SOIL SAMPLE LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC *Environmental Consulting & Management*	Compiled by: B.G.	Date: 06/30/98	Figure
	Prepared by: J.S.G.	Scale: SHOWN	9
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	Proj No: 49301J05	File No: 49301101	

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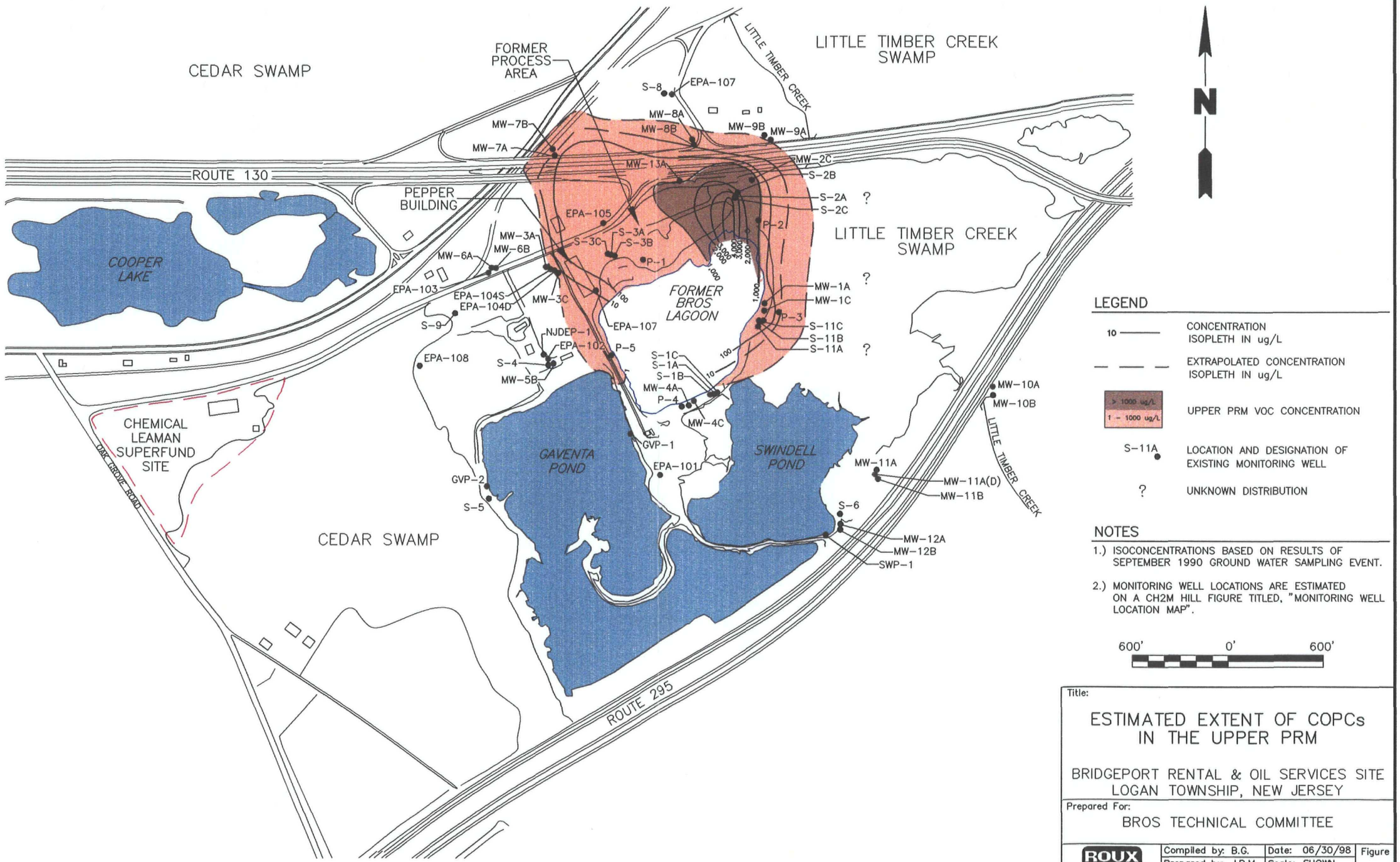

Title:

ESTIMATED EXTENT OF COPCs IN THE UPPER PRM

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 06/30/98	Figure
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	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301081	

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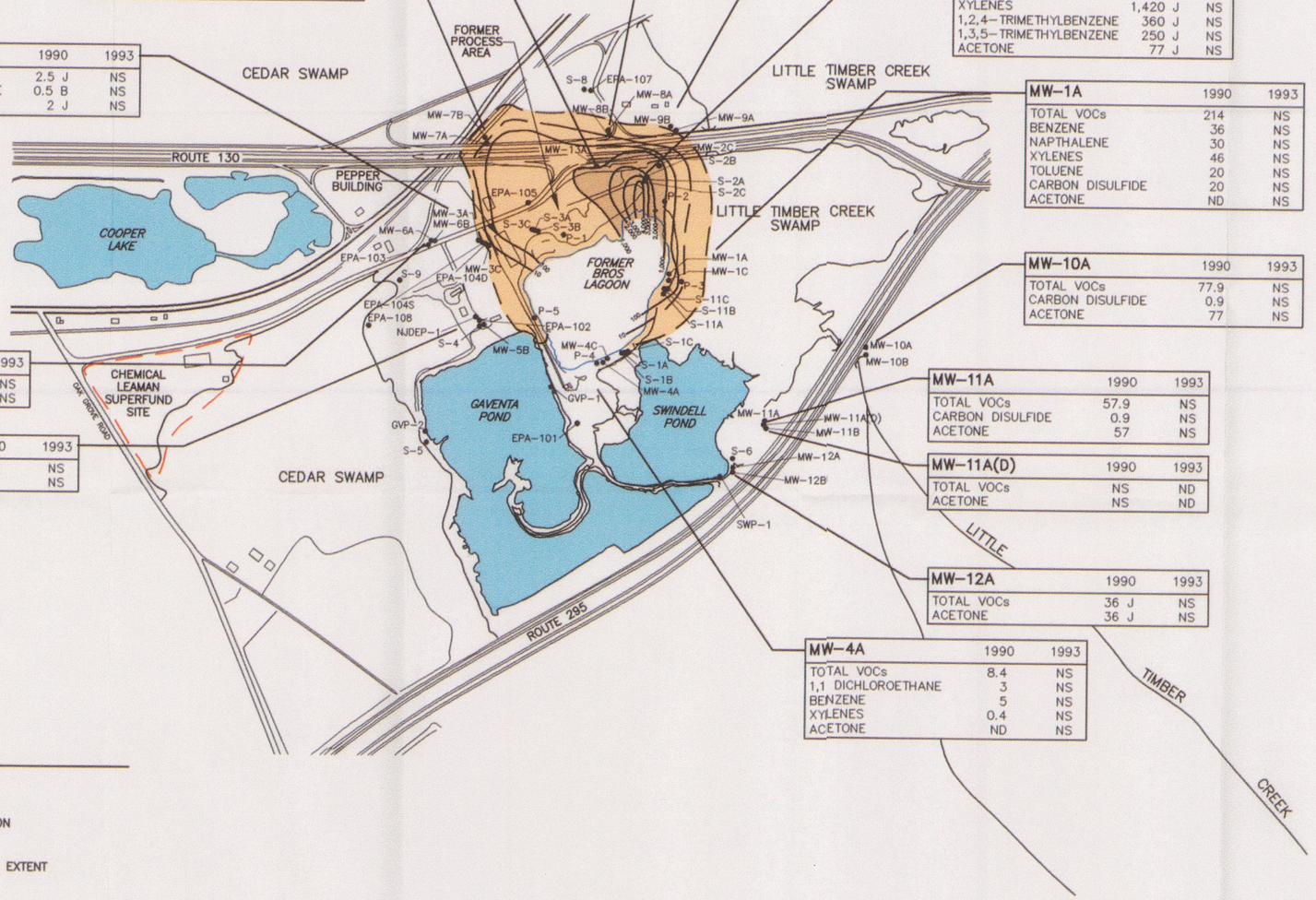


MW-13A	1990	1993
TOTAL VOCs	1020 J	NS
1,2,4-TRIMETHYLBENZENE	35	NS
CARBON DISULFIDE	910	NS
METHYLENE CHLORIDE	70 B	NS
TOLUENE	5 J	NS
ACETONE	ND	NS

MW-7A	1990	1993
TOTAL VOCs	663 J	NS
1,2,4-TRIMETHYLBENZENE	11	NS
METHYLENE CHLORIDE	16 J	NS
TOLUENE	6	NS
ACETONE	630 J	NS

MW-3A	1990	1993
TOTAL VOCs	2.5 J	NS
METHYLENE CHLORIDE	0.5 B	NS
ACETONE	2 J	NS

MW-6A	1990	1993
TOTAL VOCs	500 J	NS
ACETONE	500 J	NS

S-4	1990	1993
TOTAL VOCs	ND	NS
ACETONE	ND	NS

MW-8A	1990	1993
TOTAL VOCs	74 J	NS
ACETONE	74 J	NS

MW-9A	1990	1993
TOTAL VOCs	97 J	ND
ACETONE	97 J	ND

S-2A	1990	1993
TOTAL VOCs	5,205 J	NS
BENZENE	810 J	NS
ETHYLBENZENE	810 J	NS
XYLENES	1,420 J	NS
1,2,4-TRIMETHYLBENZENE	360 J	NS
1,3,5-TRIMETHYLBENZENE	250 J	NS
ACETONE	77 J	NS

MW-1A	1990	1993
TOTAL VOCs	214	NS
BENZENE	36	NS
NAPTHALENE	30	NS
XYLENES	46	NS
TOLUENE	20	NS
CARBON DISULFIDE	20	NS
ACETONE	ND	NS

MW-10A	1990	1993
TOTAL VOCs	77.9	NS
CARBON DISULFIDE	0.9	NS
ACETONE	77	NS

MW-11A	1990	1993
TOTAL VOCs	57.9	NS
CARBON DISULFIDE	0.9	NS
ACETONE	57	NS

MW-11A(D)	1990	1993
TOTAL VOCs	NS	ND
ACETONE	NS	ND

MW-12A	1990	1993
TOTAL VOCs	36 J	NS
ACETONE	36 J	NS

MW-4A	1990	1993
TOTAL VOCs	8.4	NS
1,1 DICHLOROETHANE	3	NS
BENZENE	5	NS
XYLENES	0.4	NS
ACETONE	ND	NS

MW-14A	1990	1993
TOTAL VOCs	NS	1.9
TOLUENE	NS	1
XYLENES	NS	0.9
ACETONE	NS	ND

MW-15A	1990	1993
TOTAL VOCs	NS	2
TOLUENE	NS	1
ACETONE	NS	1

MW-16A	1990	1993
TOTAL VOCs	NS	ND
ACETONE	NS	ND

LEGEND

10 ———	CONCENTRATION ISOPLETH IN ug/L
— — —	EXTRAPOLATED CONCENTRATION ISOPLETH IN ug/L
> 1000 ug/L 1 ~ 1000 ug/L	UPPER MIDDLE PRM LATERAL EXTENT OF VOC COPCs
S11A ●	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL
35	TOTAL VOCs INCLUDES COMPOUNDS WITH ESTIMATED CONCENTRATIONS. ONLY 5 HIGHEST CONCENTRATIONS OF VOCs PLUS ACETONE LISTED.
NS	NOT SAMPLED
ND	NOT DETECTED
J	ESTIMATED CONCENTRATION
B	COMPOUND ALSO DETECTED IN ASSOCIATED QA/QC SAMPLE

NOTES

1.) ISOCONCENTRATIONS BASED ON RESULTS OF SEPTEMBER, 1990 GROUND WATER SAMPLING EVENT. ACETONE NOT INCLUDED IN ISOCONCENTRATIONS.

2.) MONITORING WELL LOCATIONS ARE ESTIMATED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

Title:

CONCENTRATIONS OF VOC COPCs IN THE UPPER PRM

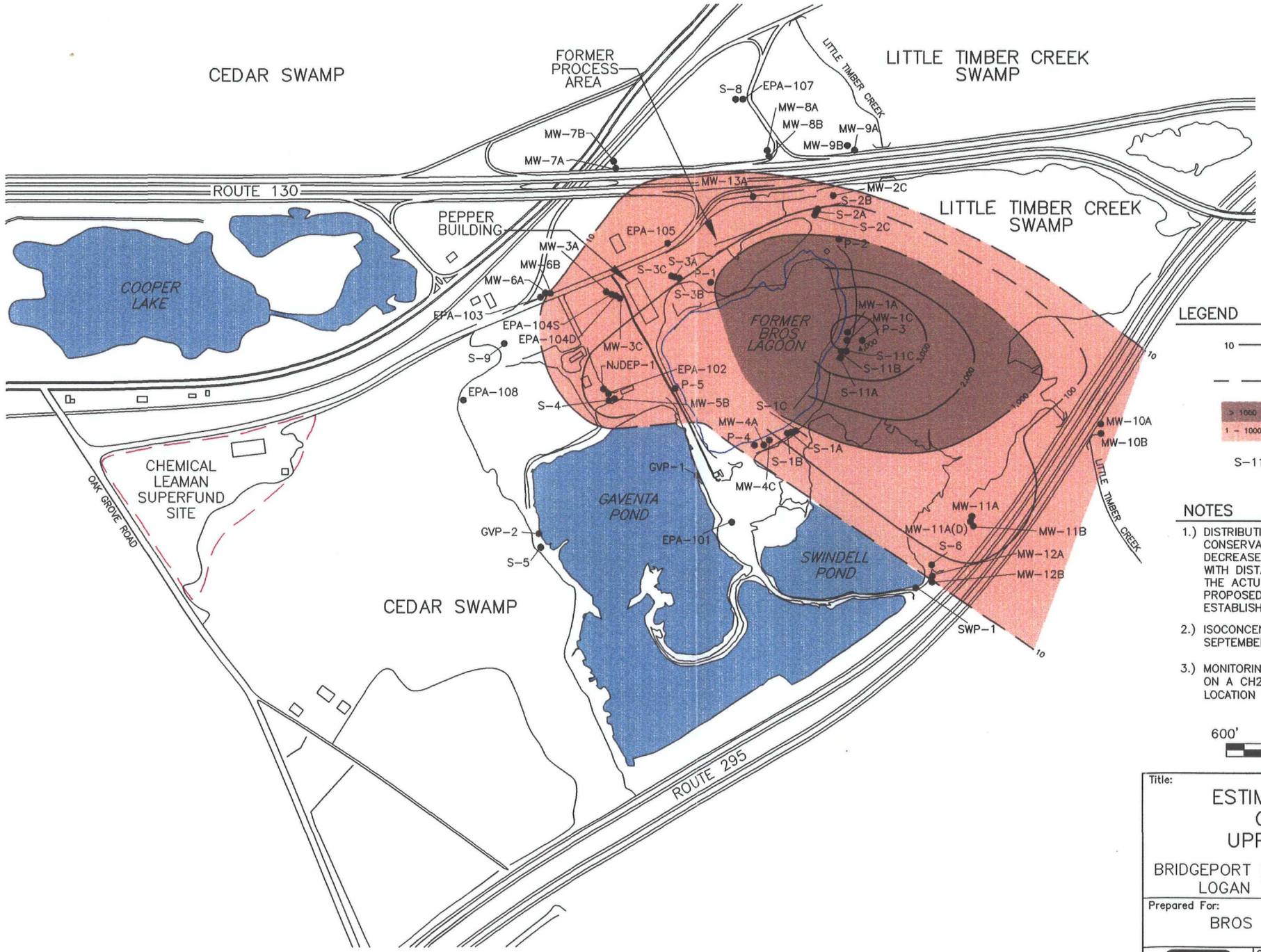
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/02/98	Figure
Prepared by: J.S.G.	Scale: SHOWN	11
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301082	

300861



LEGEND

10 ———	CONCENTRATION ISOPLETH IN ug/L
— — —	EXTRAPOLATED CONCENTRATION ISOPLETH IN ug/L
> 1000 ug/L 1 – 1000 ug/L	UPPER MIDDLE PRM VOC CONCENTRATION
S-11A ●	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL

NOTES

1.) DISTRIBUTION AND EXTENT OF VOCs HAVE BEEN CONSERVATIVELY DEPICTED ASSUMING A LINEAR DECREASE IN CONCENTRATION WITH DISTANCE. WITH DISTANCE. THE ACTUAL DECREASE THE ACTUAL IS LIKELY TO BE LOG-NORMAL. PROPOSED WELL LOCATIONS ARE INTENDED TO ESTABLISH THE VOC DISTRIBUTION.

2.) ISOCONCENTRATIONS BASED ON RESULTS OF SEPTEMBER, 1990 GROUND WATER SAMPLING EVENT.

3.) MONITORING WELL LOCATIONS ARE ESTIMATED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

600' 0' 600'

Title:

ESTIMATED EXTENT OF COPCs IN THE UPPER MIDDLE PRM

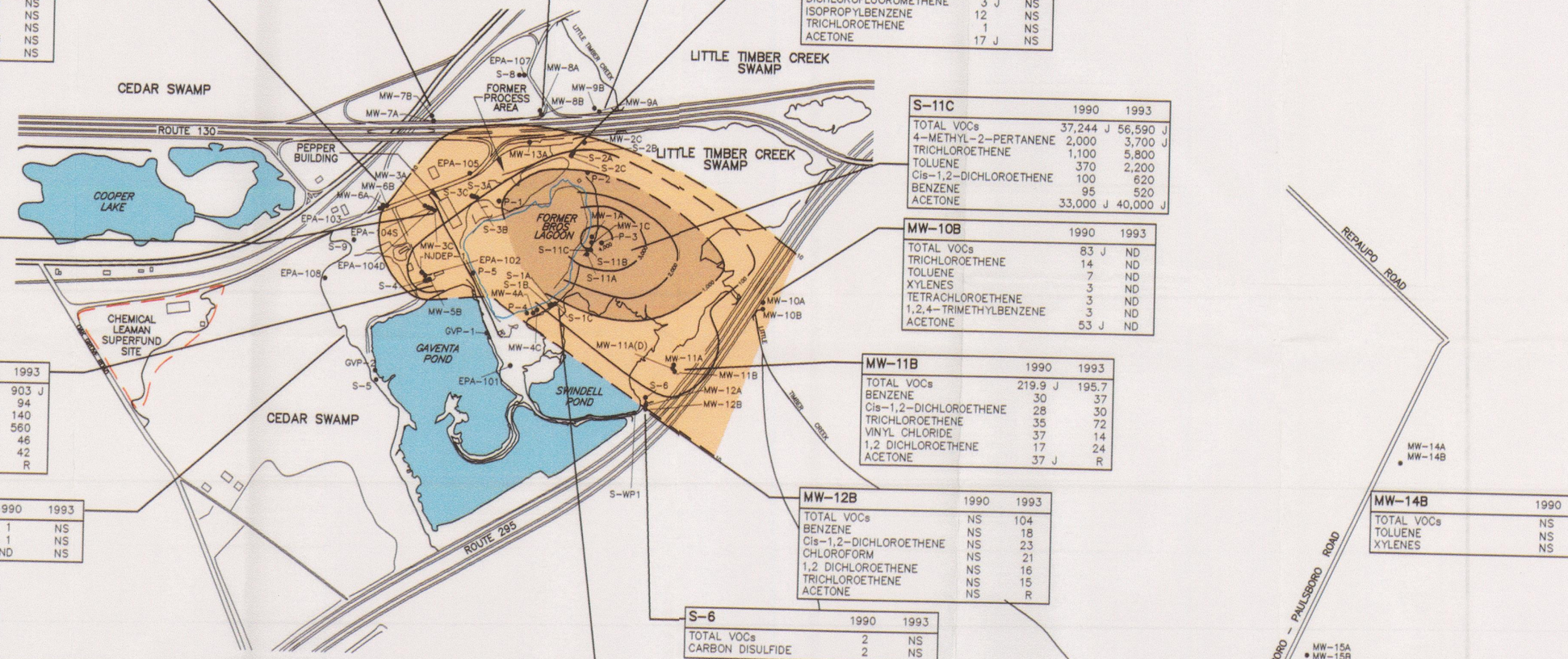
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/03/98	Figure
Prepared by: J.R.M.	Scale: SHOWN	12
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301083	

300862



MW-8B	1990	1993
TOTAL VOCs	140 J	NS
ACETONE	140 J	NS

MW-7B	1990	1993
TOTAL VOCs	3,505 J	NS
BENZENE	1	NS
Cis-1,2-DICHLOROETHENE	2	NS
1,1 DICHLOROETHANE	1	NS
TOLUENE	1	NS
ACETONE	3,500 J	NS

MW-6B	1990	1993
TOTAL VOCs	422.9 J	NS
TRICHLOROETHENE	2	NS
TOLUENE	0.6	NS
XYLENES	0.3 J	NS
ACETONE	420 J	NS

MW-9B	1990	1993
TOTAL VOCs	94 J	NS
ACETONE	94 J	NS

S-2C	1990	1993
TOTAL VOCs	37.7 J	NS
BENZENE	2	NS
DICHLOROFLUOROMETHENE	3 J	NS
ISOPROPYLBENZENE	12	NS
TRICHLOROETHENE	1	NS
ACETONE	17 J	NS

S-11C	1990	1993
TOTAL VOCs	37,244 J	56,590 J
4-METHYL-2-PERTANENE	2,000	3,700 J
TRICHLOROETHENE	1,100	5,800
TOLUENE	370	2,200
Cis-1,2-DICHLOROETHENE	100	620
BENZENE	95	520
ACETONE	33,000 J	40,000 J

S-3C	1990	1993
TOTAL VOCs	86.1 J	NS
BENZENE	12	NS
Cis-1,2-DICHLOROETHENE	2	NS
CHLOROBENZENE	4	NS
2-BUTANONE	2	NS
ACETONE	63 J	NS

MW-10B	1990	1993
TOTAL VOCs	83 J	ND
TRICHLOROETHENE	14	ND
TOLUENE	7	ND
XYLENES	3	ND
TETRACHLOROETHENE	3	ND
1,2,4-TRIMETHYLBENZENE	3	ND
ACETONE	53 J	ND

MW-5B	1990	1993
TOTAL VOCs	354 J	903 J
BENZENE	19 J	94
Cis-1,2-DICHLOROETHENE	95 J	140
TRICHLOROETHENE	210 J	560
1,2 DICHLOROETHANE	9 J	46
TETRACHLOROETHENE	ND	42
ACETONE	ND	R

MW-11B	1990	1993
TOTAL VOCs	219.9 J	195.7
BENZENE	30	37
Cis-1,2-DICHLOROETHENE	28	30
TRICHLOROETHENE	35	72
VINYL CHLORIDE	37	14
1,2 DICHLOROETHENE	17	24
ACETONE	37 J	R

EPA-108	1990	1993
TOTAL VOCs	1	NS
CARBON DISULFATE	1	NS
ACETONE	ND	NS

MW-12B	1990	1993
TOTAL VOCs	NS	104
BENZENE	NS	18
Cis-1,2-DICHLOROETHENE	NS	23
CHLOROFORM	NS	21
1,2 DICHLOROETHENE	NS	16
TRICHLOROETHENE	NS	15
ACETONE	NS	R

MW-14B	1990	1993
TOTAL VOCs	NS	2
TOLUENE	NS	1
XYLENES	NS	1

S-6	1990	1993
TOTAL VOCs	2	NS
CARBON DISULFIDE	2	NS

MW-15B	1990	1993
TOTAL VOCs	NS	ND
ACETONE	NS	ND

S-1C	1990	1993
TOTAL VOCs	ND	0.6
TOLUENE	ND	0.6
ACETONE	ND	ND

MW-16B	1990	1993
TOTAL VOCs	NS	ND
ACETONE	NS	ND

LEGEND

10 ———	CONCENTRATION ISOPLETH IN ug/L
— — —	EXTRAPOLATED CONCENTRATION ISOPLETH IN ug/L
> 1000 ug/L 1 - 1000 ug/L	UPPER MIDDLE PRM VOC CONCENTRATIONS
S-11A •	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL
354	RESULTS IN ug/L. TOTAL VOCs INCLUDES COMPOUNDS WITH ESTIMATED CONCENTRATIONS. ONLY 5 HIGHEST CONCENTRATIONS OF VOCs PLUS ACETONE LISTED.
NS	NOT SAMPLED
ND	NOT DETECTED
J	ESTIMATED CONCENTRATION
B	COMPOUND ALSO DETECTED IN ASSOCIATED QA/QC SAMPLE
R	DATA REJECTED

NOTES

1.) DISTRIBUTION AND EXTENT OF VOCs HAVE BEEN CONSERVATIVELY DEPICTED ASSUMING A LINEAR DECREASE IN CONCENTRATION WITH DISTANCE. THE ACTUAL DECREASE IS LIKELY TO BE LOG-NORMAL. PROPOSED WELL LOCATIONS ARE INTENDED TO ESTABLISH THE VOC DISTRIBUTION.

2.) ISOCONCENTRATIONS BASED ON RESULTS OF SEPTEMBER 1990 GROUND WATER SAMPLING EVENT.

3.) MONITORING WELL LOCATIONS ARE ESTIMATED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

800' 0' 800'

Title:

ESTIMATED EXTENT OF VOC COPCs IN THE UPPER MIDDLE PRM

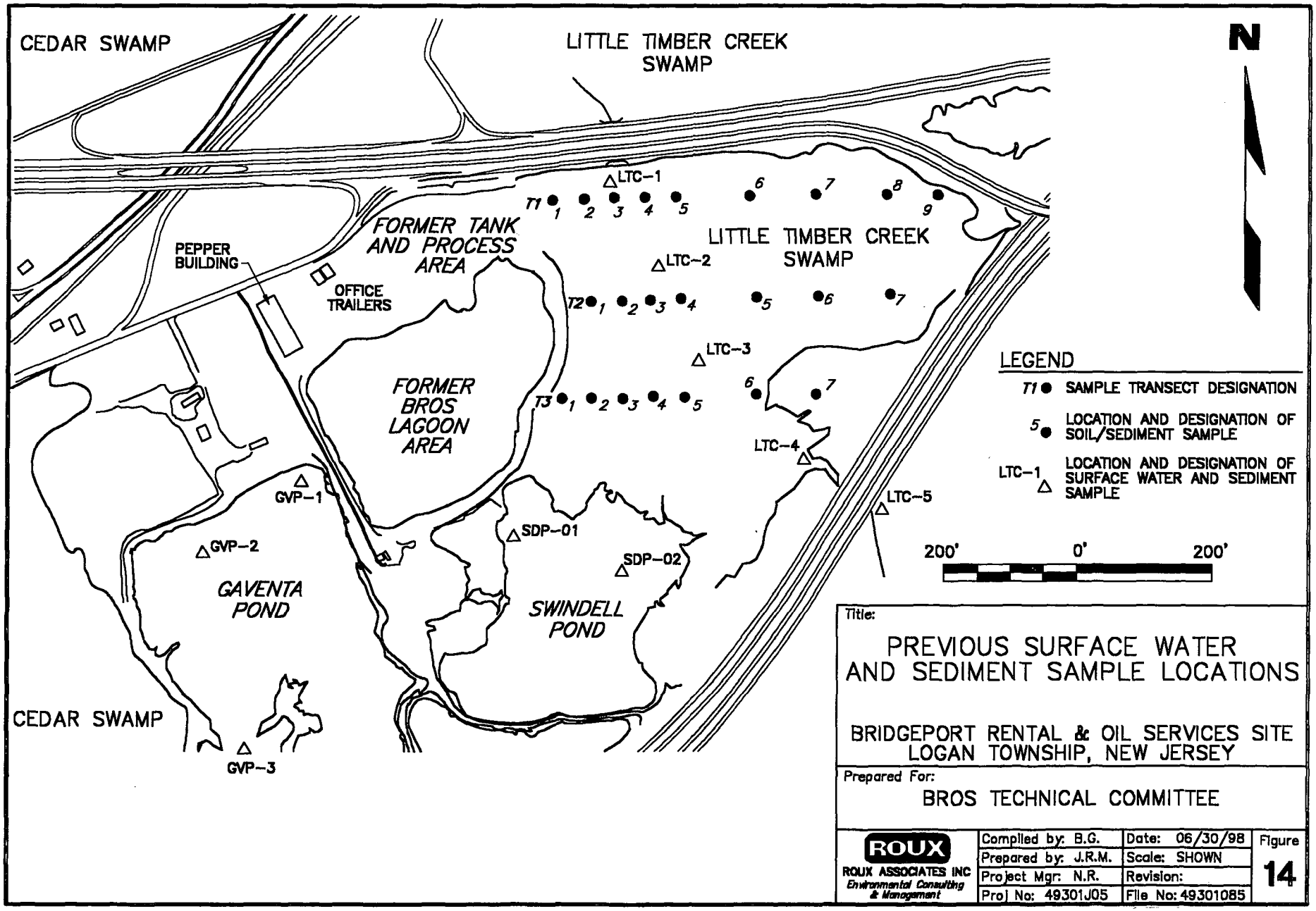
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: J.L.	Date: 07/01/98	Figure
Prepared by: J.S.G.	Scale: SHOWN	13
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301084	

300863



Title:

PREVIOUS SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

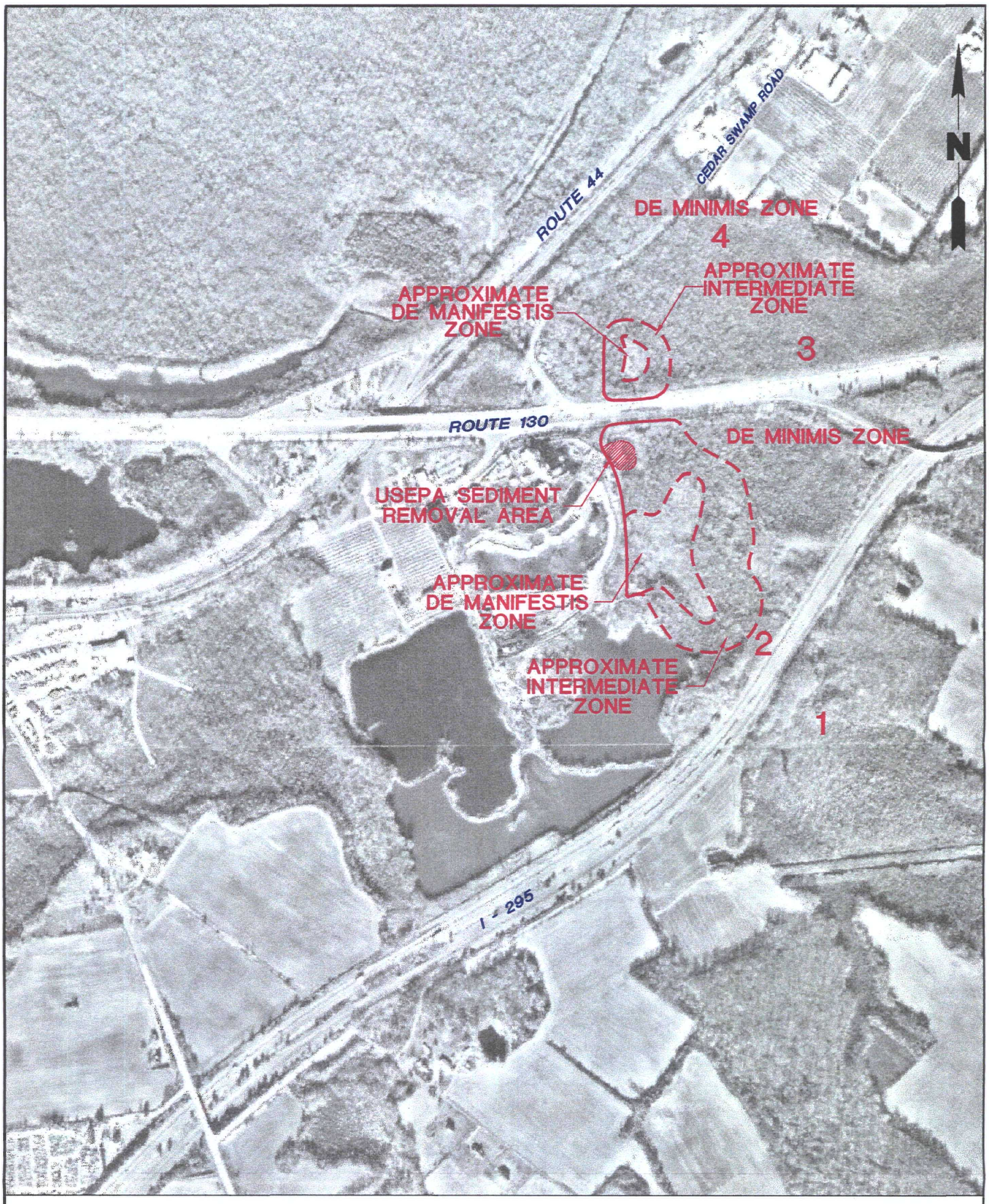
Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 06/30/98	Figure
Prepared by: J.R.M.	Scale: SHOWN	14
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301085	

300864



600' 0' 600'

LEGEND

ZONE BOUNDARY – DASHED WHERE APPROXIMATE

1 APPROXIMATE LOCATION OF CANDIDATE REFERENCE AREA

SOURCE

1.) PHOTOGRAPH TAKEN DECEMBER 29, 1994 WHEN ON-SITE INCINERATOR WAS ACTIVE.

Title:

CONCEPTUAL REPRESENTATION OF ECOLOGICAL RISK ASSESSMENT ZONES

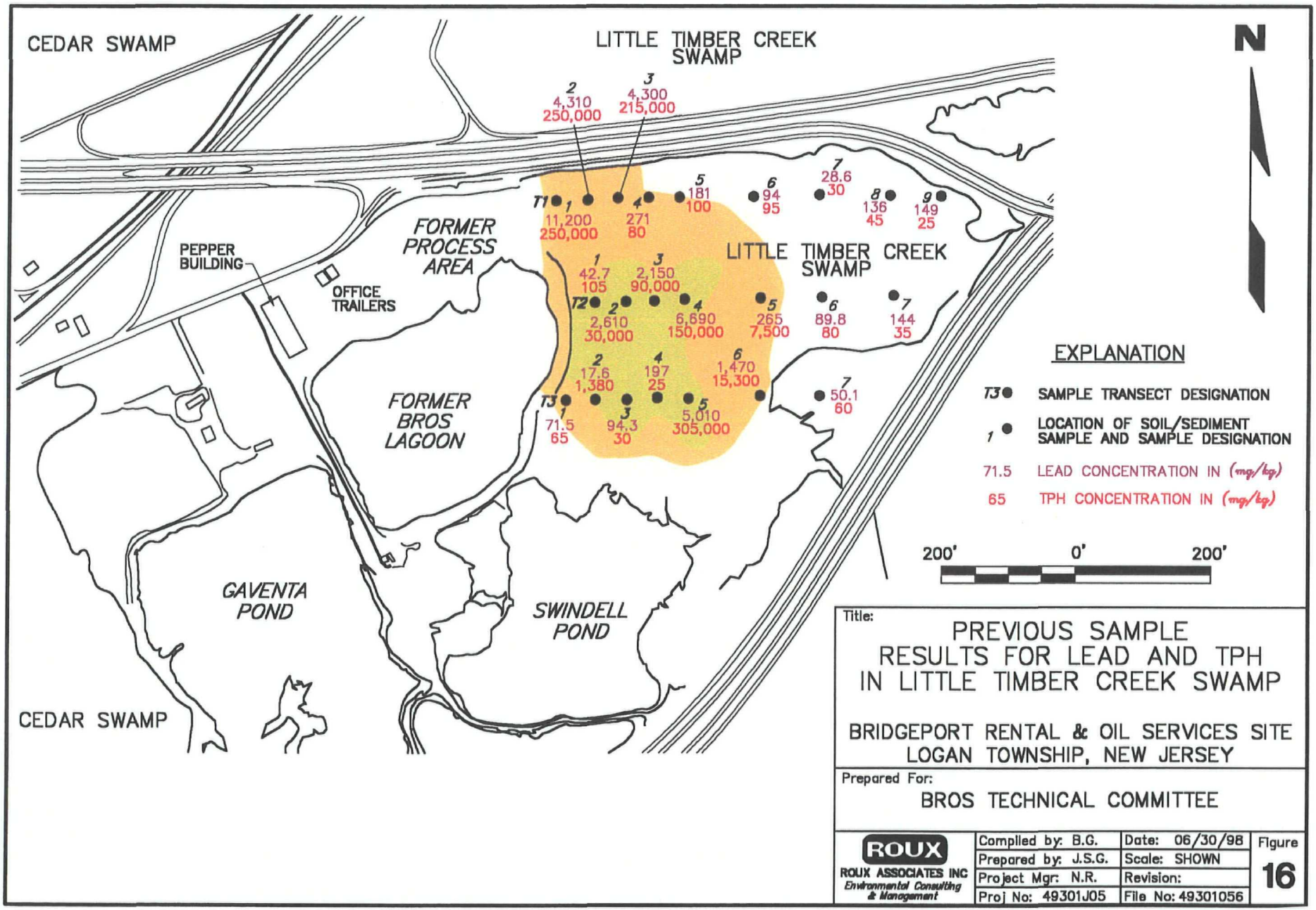
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC *Environmental Consulting & Management*	Compiled by: N.R.	Date: 07/03/98	Figure 15
	Prepared by: J.S.G.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301096	

300865



Title:

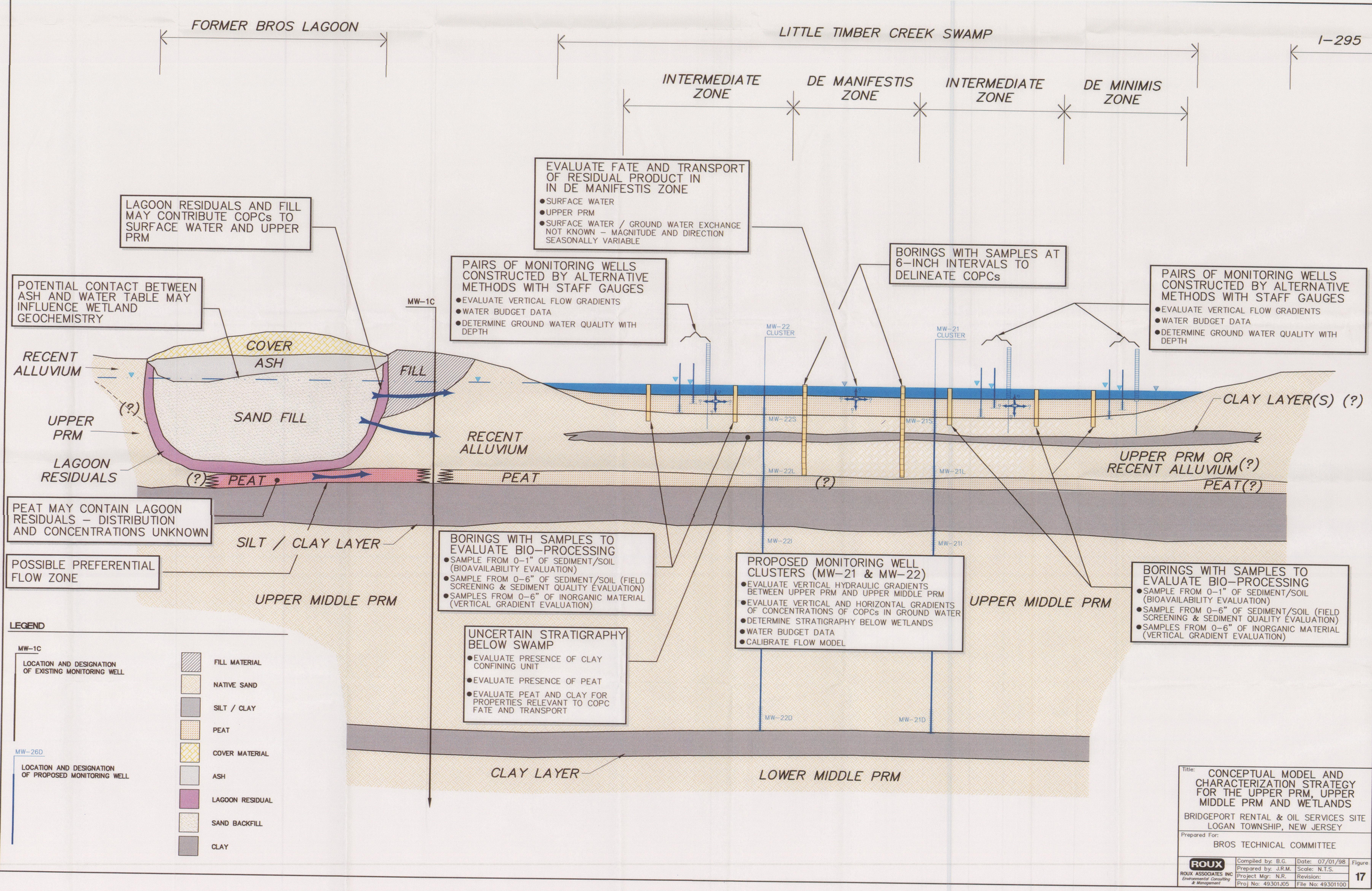
PREVIOUS SAMPLE RESULTS FOR LEAD AND TPH IN LITTLE TIMBER CREEK SWAMP

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 06/30/98	Figure 16
	Prepared by: J.S.G.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301056	

300866



Title: CONCEPTUAL MODEL AND CHARACTERIZATION STRATEGY FOR THE UPPER PRM, UPPER MIDDLE PRM AND WETLANDS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For: BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/01/98	Figure	
Prepared by: J.R.M.	Scale: N.T.S.	17	
Project Mgr: N.R.	Revision:		
Proj No: 49301J05	File No: 49301100		

300867

LEGEND

- ▲ MONITORING WELL CLUSTER
- ▲ EXISTING UPPER PRM MONITORING WELL
- + MONITORING WELL AND STAFF GAUGE CLUSTER
- ● STAFF GAUGE
- ■ FLOW MEASUREMENT STATION

600' 0' 600'

NOTES

1.) FM-3 AND FM-4 ARE LOCATED AT DRAINAGE CULVERTS ADJACENT TO ROUTE I-295.

SOURCE

1.) PHOTOGRAPH TAKEN DECEMBER 29, 1994 WHEN ON-SITE INCINERATOR WAS ACTIVE.

Title: WATER BUDGET ANALYSIS DATA POINTS FOR EVALUATION OF SURFACE WATER AND GROUND WATER EXCHANGE

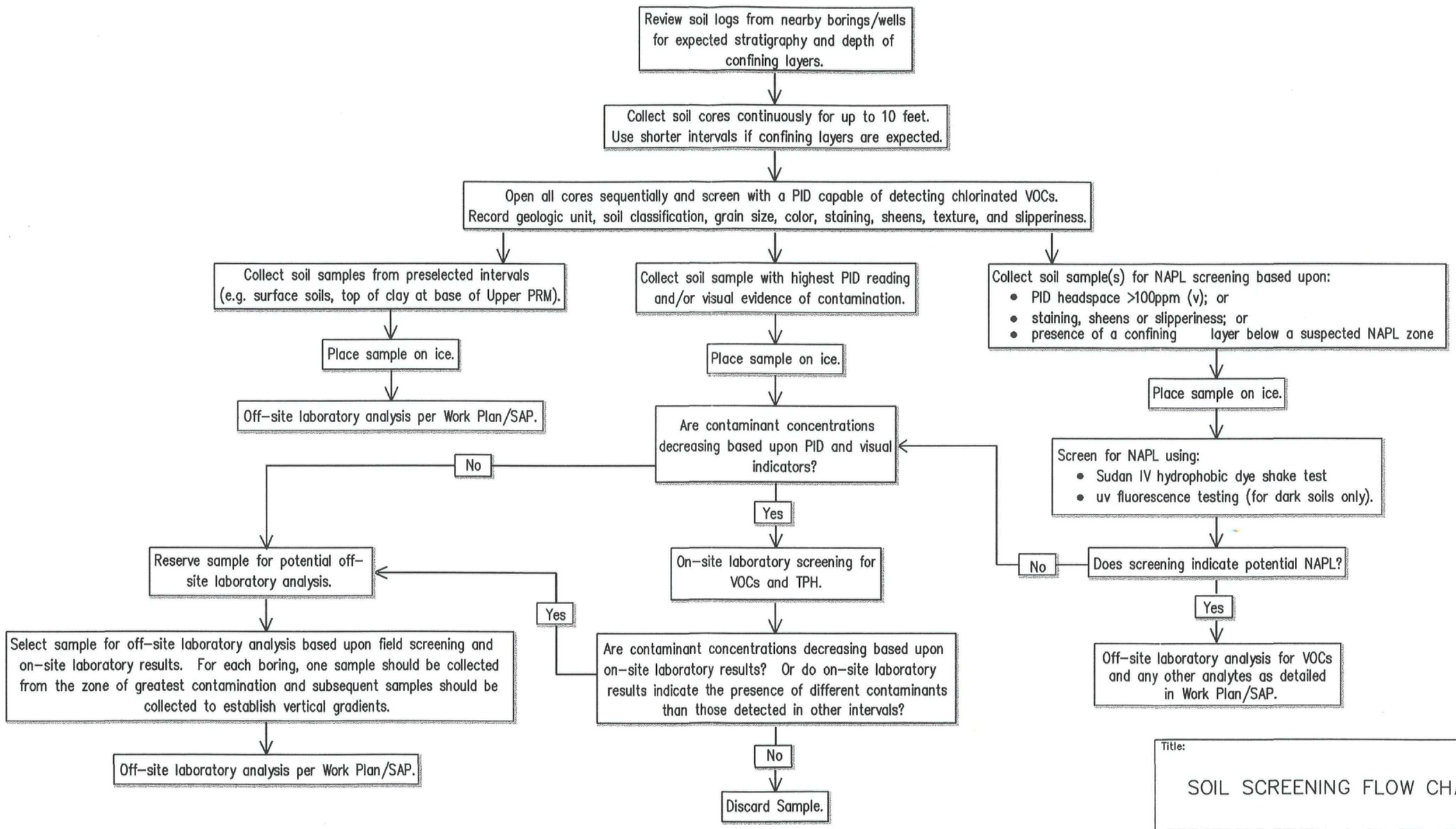
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: N.R.	Date: 12/04/98	Figure	
Prepared by: J.S.G.	Scale: SHOWN	18	
Project Mgr: N.R.	Revision:		
Proj No: 49301J05	File No: 49301102		

300868



Title:

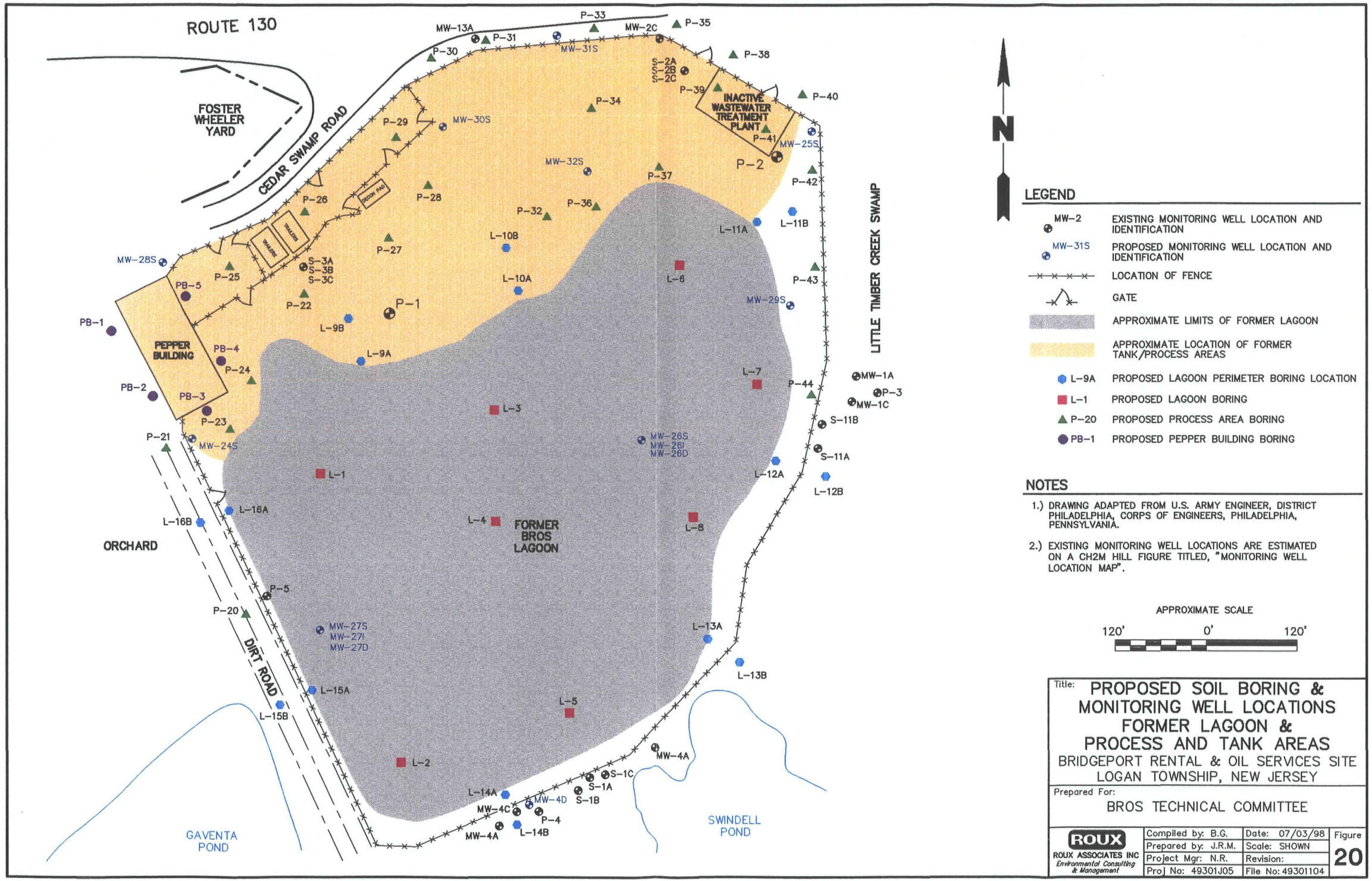
SOIL SCREENING FLOW CHART

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC *Environmental Consulting & Management*	Compiled by: B.G.	Date: 07/03/98	Figure 19
	Prepared by: J.R.M.	Scale: N.T.S.	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301105	

300869



LEGEND

MW-2	EXISTING MONITORING WELL LOCATION AND IDENTIFICATION
MW-31S	PROPOSED MONITORING WELL LOCATION AND IDENTIFICATION
	LOCATION OF FENCE
	GATE
	APPROXIMATE LIMITS OF FORMER LAGOON
	APPROXIMATE LOCATION OF FORMER TANK/PROCESS AREAS
L-9A	PROPOSED LAGOON PERIMETER BORING LOCATION
L-1	PROPOSED LAGOON BORING
P-20	PROPOSED PROCESS AREA BORING
PB-1	PROPOSED PEPPER BUILDING BORING

NOTES

1.) DRAWING ADAPTED FROM U.S. ARMY ENGINEER, DISTRICT PHILADELPHIA, CORPS OF ENGINEERS, PHILADELPHIA, PENNSYLVANIA.

2.) EXISTING MONITORING WELL LOCATIONS ARE ESTIMATED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

APPROXIMATE SCALE

120' 0' 120'

Title: PROPOSED SOIL BORING & MONITORING WELL LOCATIONS FORMER LAGOON & PROCESS AND TANK AREAS

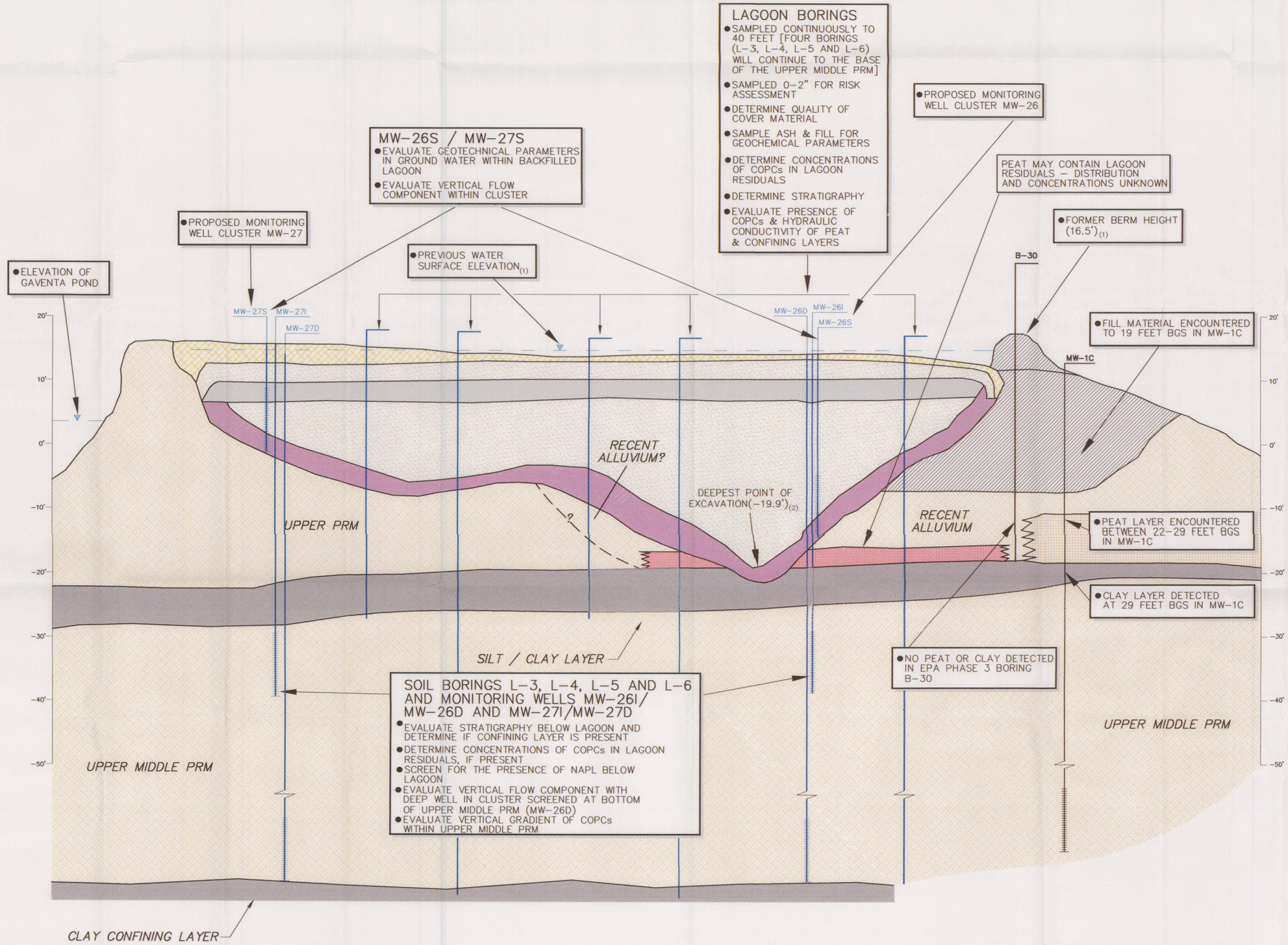
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/03/98	Figure	
Prepared by: J.R.M.	Scale: SHOWN	20	
Project Mgr: N.R.	Revision:		
Proj No: 49301J05	File No: 49301104		

300870



LEGEND

MW-1C — LOCATION AND DESIGNATION OF EXISTING MONITORING WELL

B-30 — LOCATION AND DESIGNATION OF EXISTING SOIL BORING

MW-26D — LOCATION AND DESIGNATION OF PROPOSED MONITORING WELL

LOCATION OF PROPOSED SOIL BORING

- FILL MATERIAL
- NATIVE SAND
- SILT / CLAY
- PEAT
- COVER MATERIAL
- ASH
- LAGOON RESIDUAL
- SAND BACKFILL
- CLAY

NOTES

(1) NUS CORPORATION, 1983. TOPOGRAPHIC MAP OF BROS SITE AND SURROUNDING AREAS. DRAWING No. 0707-22-01.

(2) EBASCO CONSTRUCTORS INC., 1995. DESIGN EXCAVATION LIMITS WITH ADDITIONAL EXCAVATION LIMITS. DRAWING No. EXLIMITS.DWG.

50' 0' 50'

Title:

CONCEPTUAL ILLUSTRATION OF SAMPLING ACTIVITIES AND RATIONALE IN FORMER LAGOON

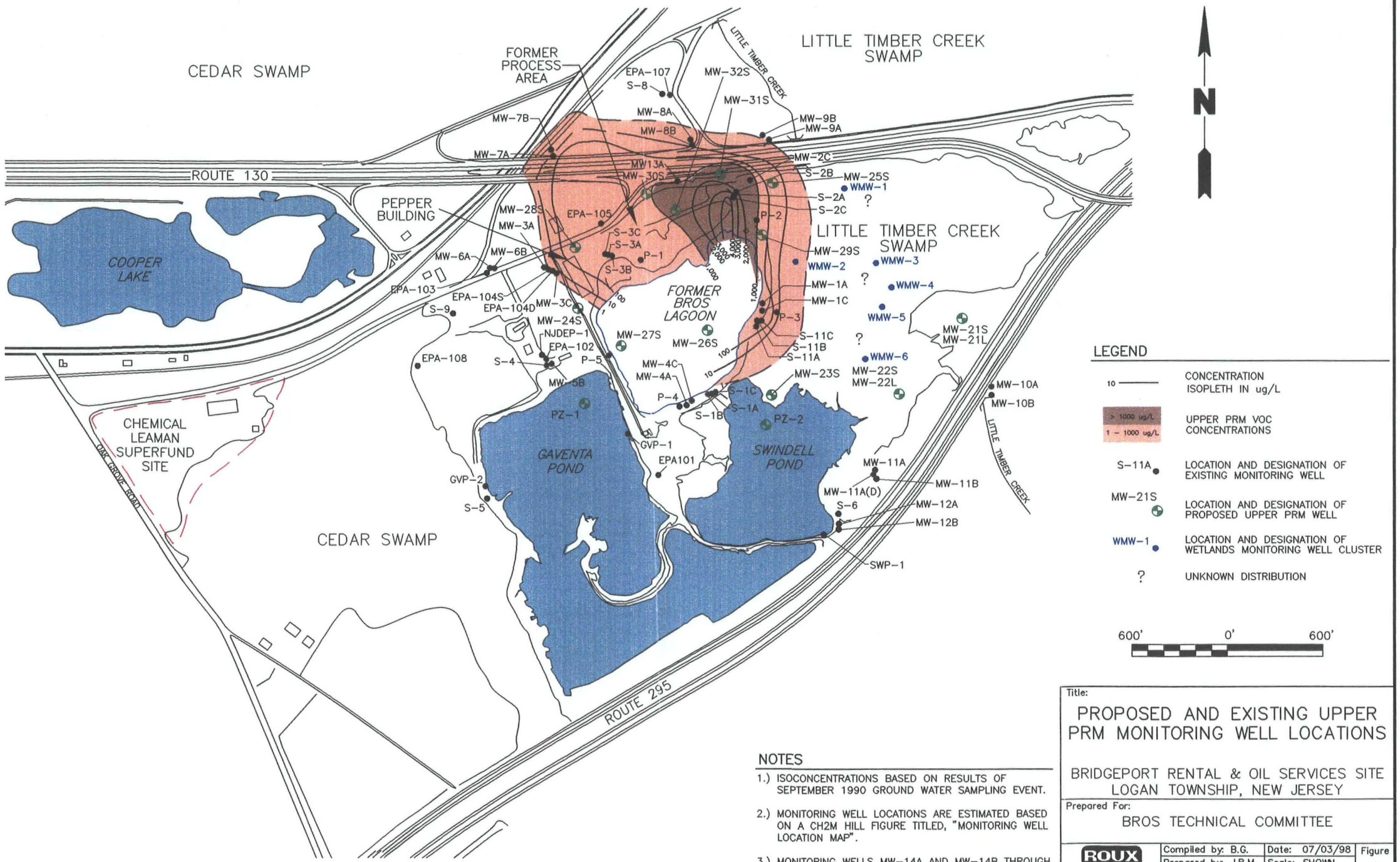
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/01/98	Figure
Prepared by: J.R.M.	Scale: SHOWN	21
Project Mgr: N.R.		
Proj No: 49301J05	File No: 49301095	

300871



NOTES

1.) ISOCONCENTRATIONS BASED ON RESULTS OF SEPTEMBER 1990 GROUND WATER SAMPLING EVENT.

2.) MONITORING WELL LOCATIONS ARE ESTIMATED BASED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

3.) MONITORING WELLS MW-14A AND MW-14B THROUGH MW-16A AND MW-16B LOCATED TO THE SOUTHEAST ARE NOT DEPICTED.

Title:

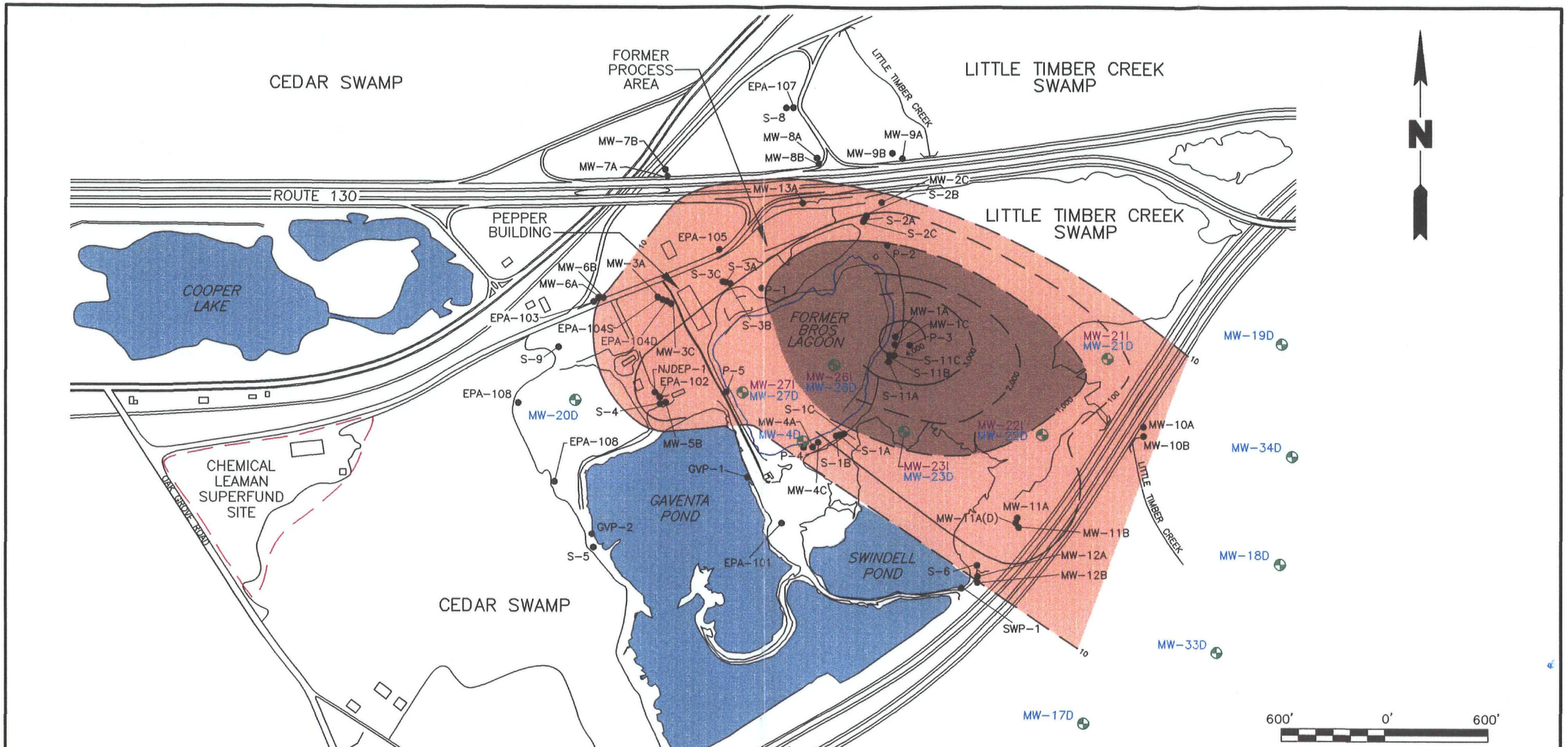
PROPOSED AND EXISTING UPPER PRM MONITORING WELL LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC *Environmental Consulting & Management*	Compiled by: B.G.	Date: 07/03/98	Figure 22
	Prepared by: J.R.M.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301087	

300872



LEGEND

— —	EXTRAPOLATED CONCENTRATION ISOPLETH
10 ———	CONCENTRATION ISOPLETH IN ug/L
> 1000 ug/L / 1 – 1000 ug/L	UPPER MIDDLE PRM VOC CONCENTRATIONS
S-11A ●	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL
MW-23I / MW-23D ⊕	LOCATION AND DESIGNATION OF PROPOSED UPPER MIDDLE PRM WELL

NOTES

1.) DISTRIBUTION AND EXTENT OF VOCs HAVE BEEN CONSERVATIVELY DEPICTED ASSUMING A LINEAR DECREASE IN CONCENTRATION WITH DISTANCE. THE ACTUAL DECREASE IS LIKELY TO BE LOG-NORMAL. PROPOSED WELL LOCATIONS ARE INTENDED TO ESTABLISH THE VOC DISTRIBUTION.

2.) ISOCONCENTRATIONS BASED ON RESULTS OF SEPTEMBER, 1990 GROUND WATER SAMPLING EVENT.

3.) EXISTING MONITORING WELL LOCATIONS ARE ESTIMATED BASED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

3.) MONITORING WELLS MW-14A AND MW-14B THROUGH MW-16A AND MW-16B LOCATED TO THE SOUTHEAST ARE NOT DEPICTED.

Title:

PROPOSED AND EXISTING UPPER MIDDLE PRM MONITORING WELL LOCATIONS

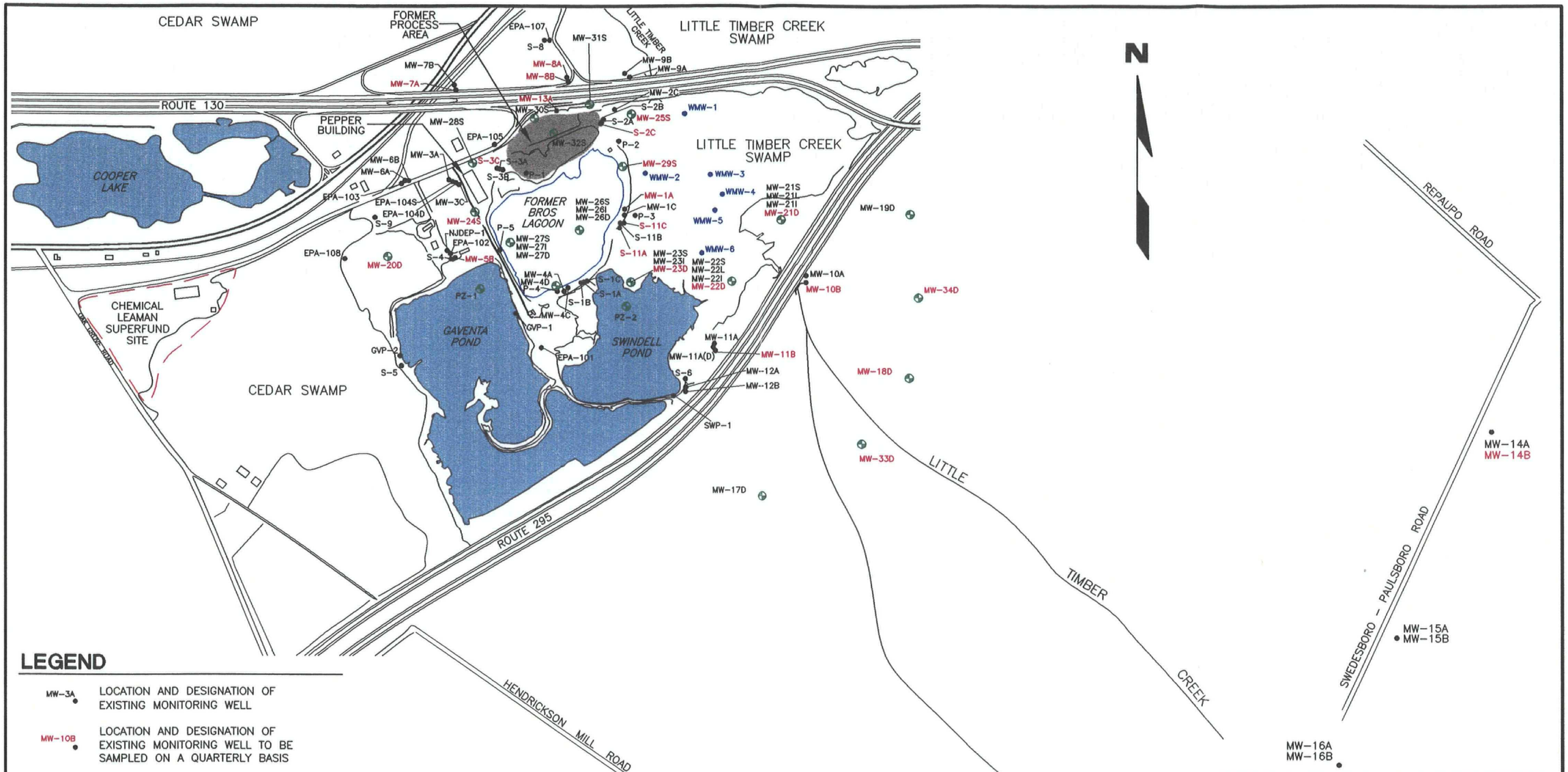
BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/02/98	Figure 23
Prepared by: J.R.M.	Scale: SHOWN	
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301091	

300873



LEGEND

MW-3A	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL
MW-10B	LOCATION AND DESIGNATION OF EXISTING MONITORING WELL TO BE SAMPLED ON A QUARTERLY BASIS
MW-17D	LOCATION AND DESIGNATION OF PROPOSED WELL
MW-18D	LOCATION AND DESIGNATION OF PROPOSED WELL ANTICIPATED FOR INCLUSION IN QUARTERLY MONITORING PROGRAM
WMW-1	LOCATION AND DESIGNATION OF WETLANDS MONITORING WELL CLUSTER

NOTES

1.) MONITORING WELL LOCATIONS ARE ESTIMATED BASED ON A CH2M HILL FIGURE TITLED, "MONITORING WELL LOCATION MAP".

800' 0' 800'

APPROXIMATE SCALE

Title:

LOCATIONS OF WELLS SELECTED FOR QUARTERLY MONITORING

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 12/01/98	Figure
Prepared by: J.R.M.	Scale: SHOWN	24
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301090	

300874

600' 0' 600'

LEGEND

- ● SEDIMENT SAMPLE LOCATION
- ▲ SURFACE WATER AND SEDIMENT SAMPLING LOCATION

SOURCE

1.) PHOTOGRAPH TAKEN DECEMBER 29, 1994 WHEN ON-SITE INCINERATOR WAS ACTIVE.

Title:

SAMPLING LOCATIONS FOR GAVENTA AND SWINDELL PONDS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

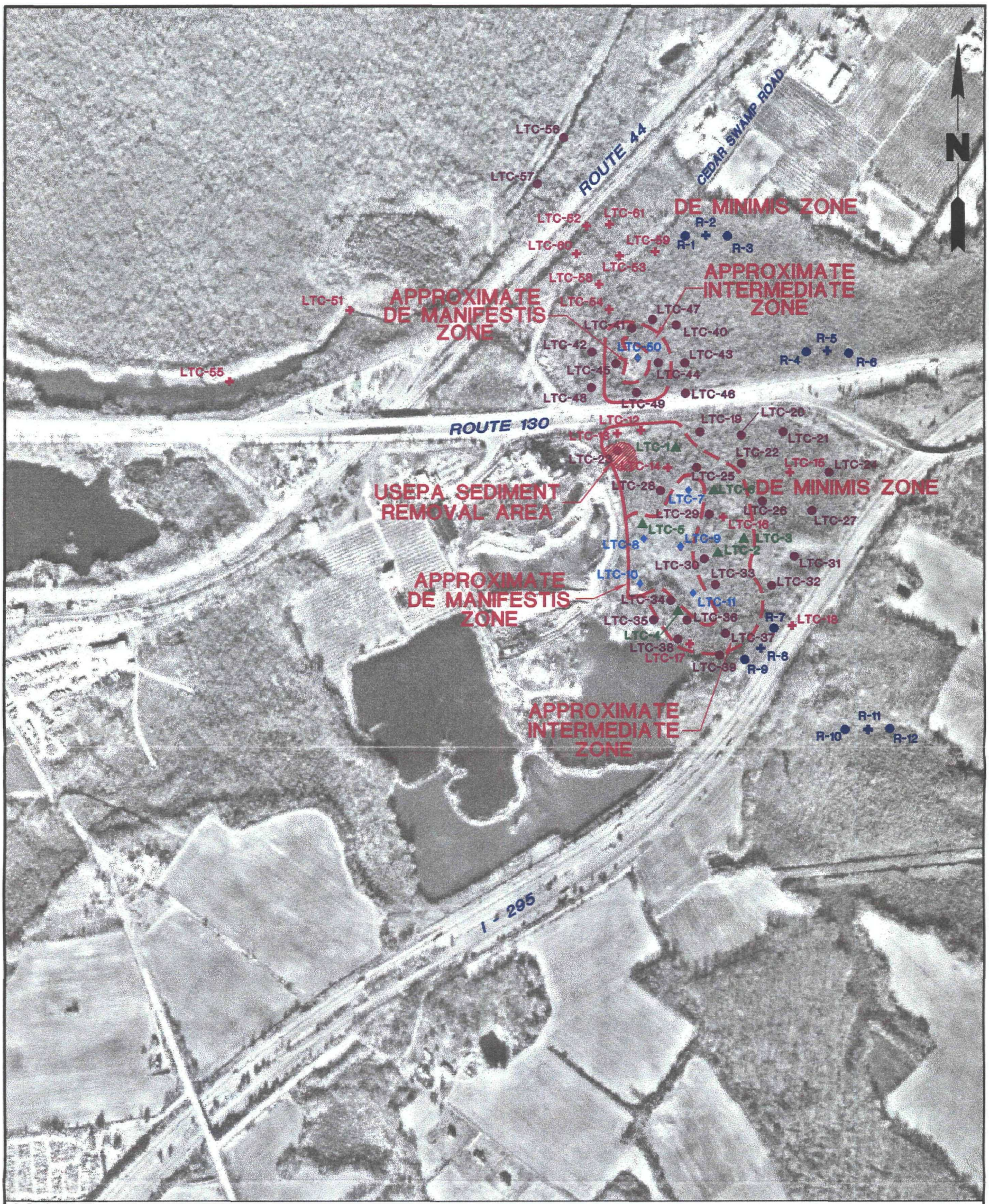
Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: N.R.	Date: 12/07/98	Figure
Prepared by: J.S.G.	Scale: SHOWN	25
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301097	

300875



LEGEND

- ZONE BOUNDARY – DASHED WHERE APPROXIMATE
- SEDIMENT SAMPLING LOCATION (REFERENCE AREA)
- SEDIMENT AND SURFACE WATER SAMPLING LOCATION (REFERENCE AREA)
- SEDIMENT AND SURFACE WATER SAMPLING LOCATION
- SEDIMENT SAMPLING LOCATION (RISK ASSESSMENT)
- MONITORING WELL, SEDIMENT AND SURFACE WATER SAMPLING LOCATION
- SEDIMENT SAMPLING LOCATION (REMEDIAL ASSESSMENT)

SOURCE

1.) PHOTOGRAPH TAKEN DECEMBER 29, 1994 WHEN ON-SITE INCINERATOR WAS ACTIVE.

600' 0' 600'

Title:

WETLANDS SAMPLING LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

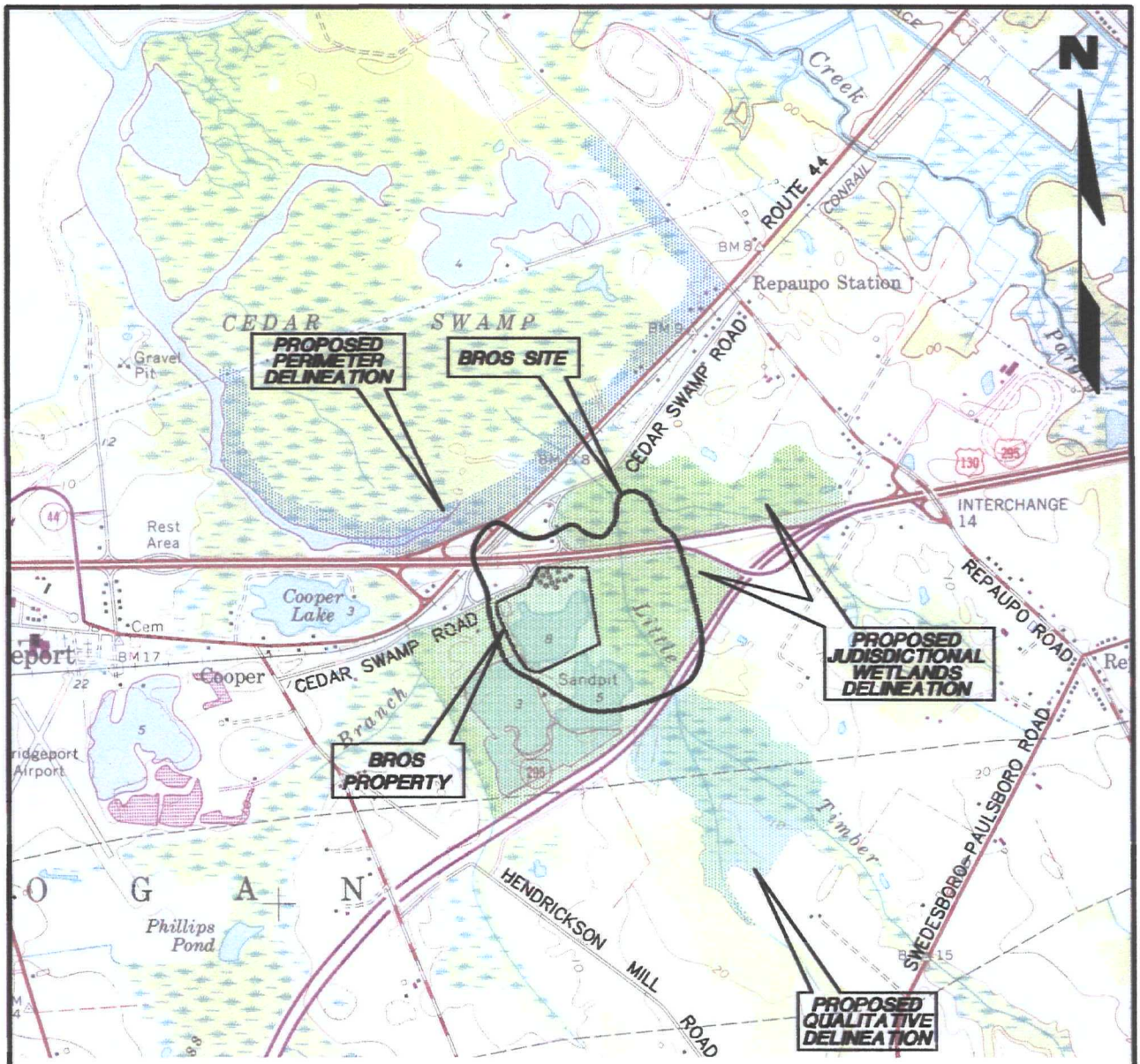
Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: N.R.	Date: 07/01/98	Figure
Prepared by: J.S.G.	Scale: SHOWN	26
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301099	

300876



QUADRANGLE LOCATION

2,000' 0' 2,000'

LEGEND

APPROXIMATE SITE BOUNDARY

APPROXIMATE PROPERTY BOUNDARY

SOURCE:

U.S.G.S. BRIDGEPORT, N.J., QUADRANGLE 1967
7.5 MINUTE SERIES (TOPOGRAPHIC)
PHOTOREVISED 1986
CONTOUR INTERVAL 10 FEET

Title:

AREAS OF PROPOSED WETLANDS DELINEATION

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 07/02/98	Figure 27
	Prepared by: J.R.M.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301110	

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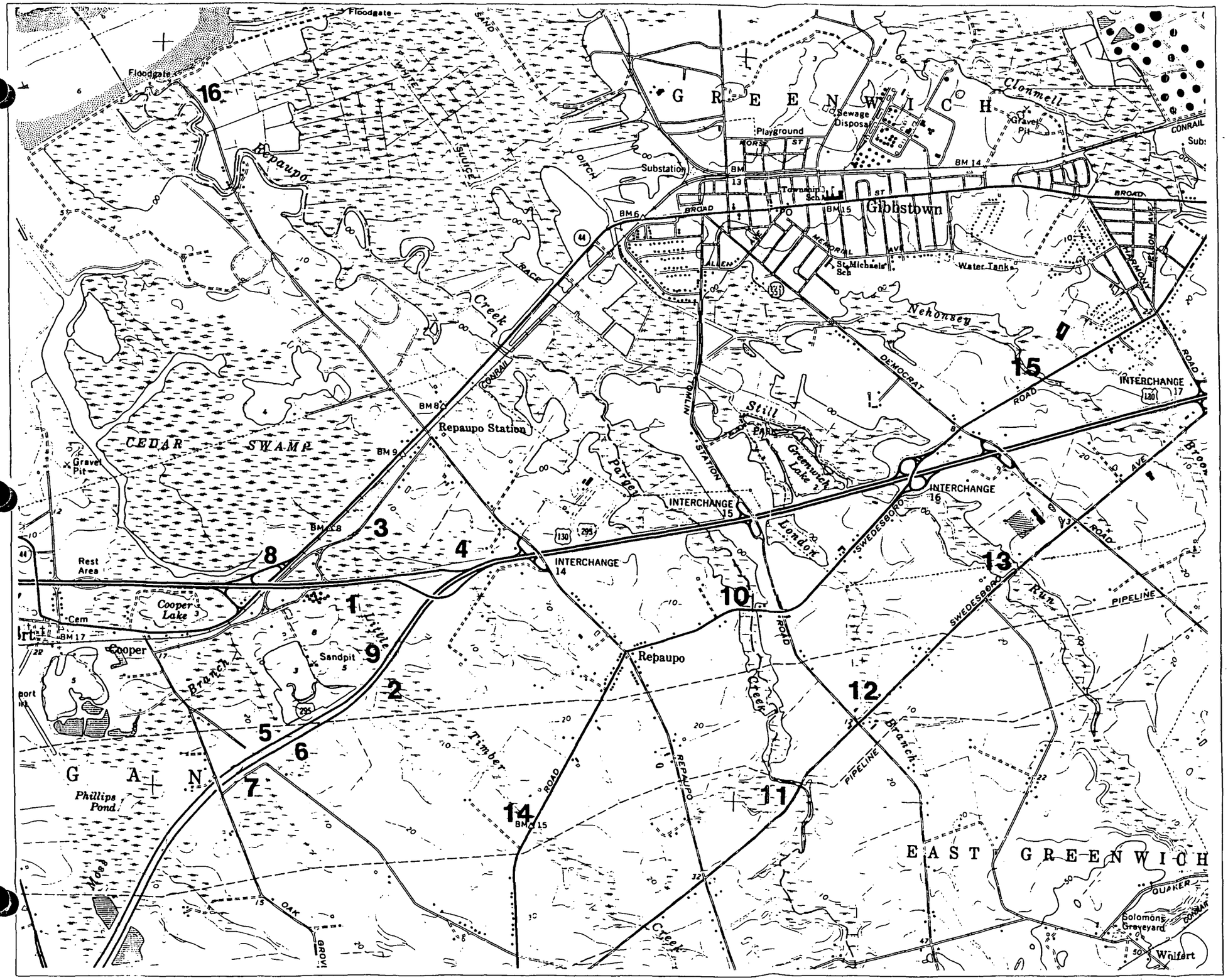


APPROXIMATE SCALE
1" = 2000'

POTENTIAL REFERENCE SITE LOCATIONS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NJ

SOURCE: USGS BRIDGEPORT QUADRANGLE

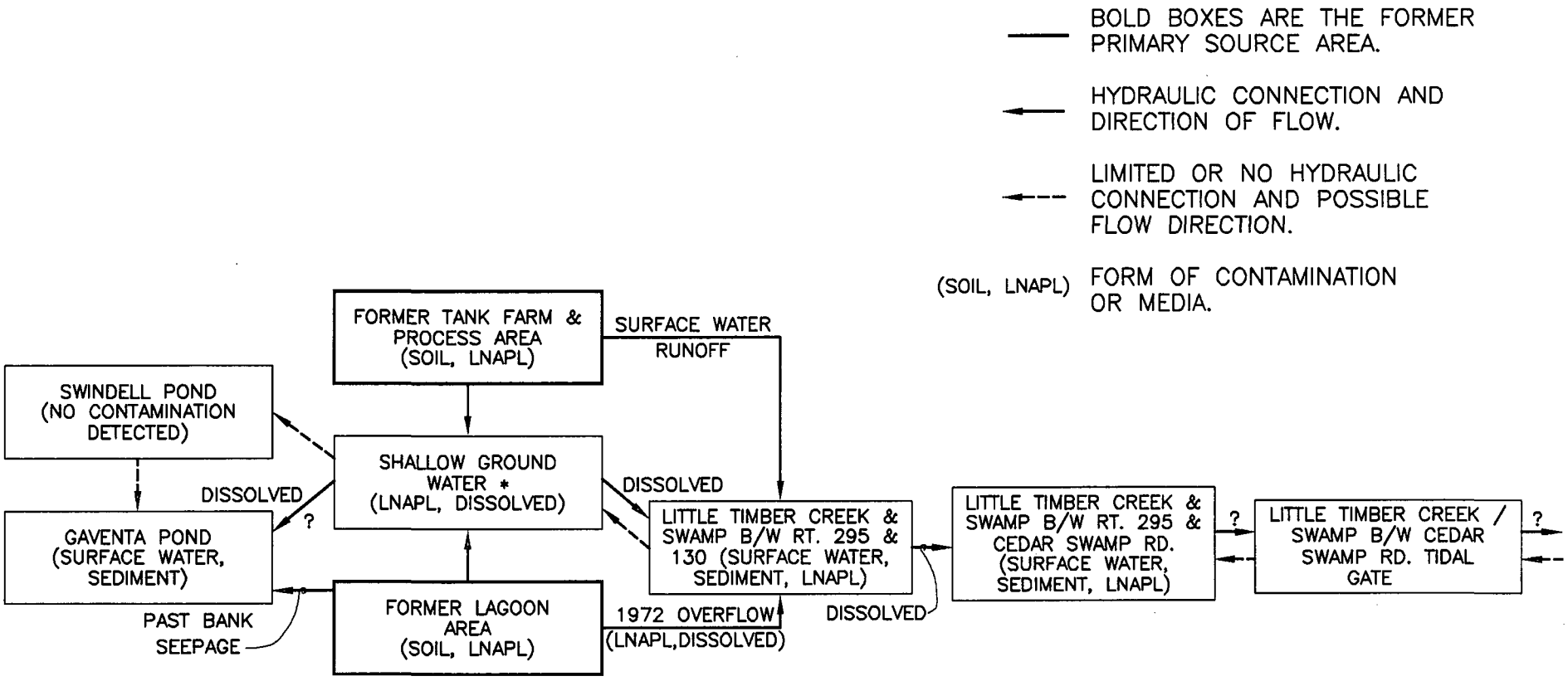
Prepared For:

BROS TECHNICAL COMMITTEE

FIGURE 28

O'BRIEN & GERE ENGINEERS, INC.

GENERAL CONCEPTUAL MODEL ON THE DISTRIBUTION AND POTENTIAL TRANSPORT PATHWAYS FOR THE ECOLOGICAL RISK EVALUATION AT THE BROS SITE

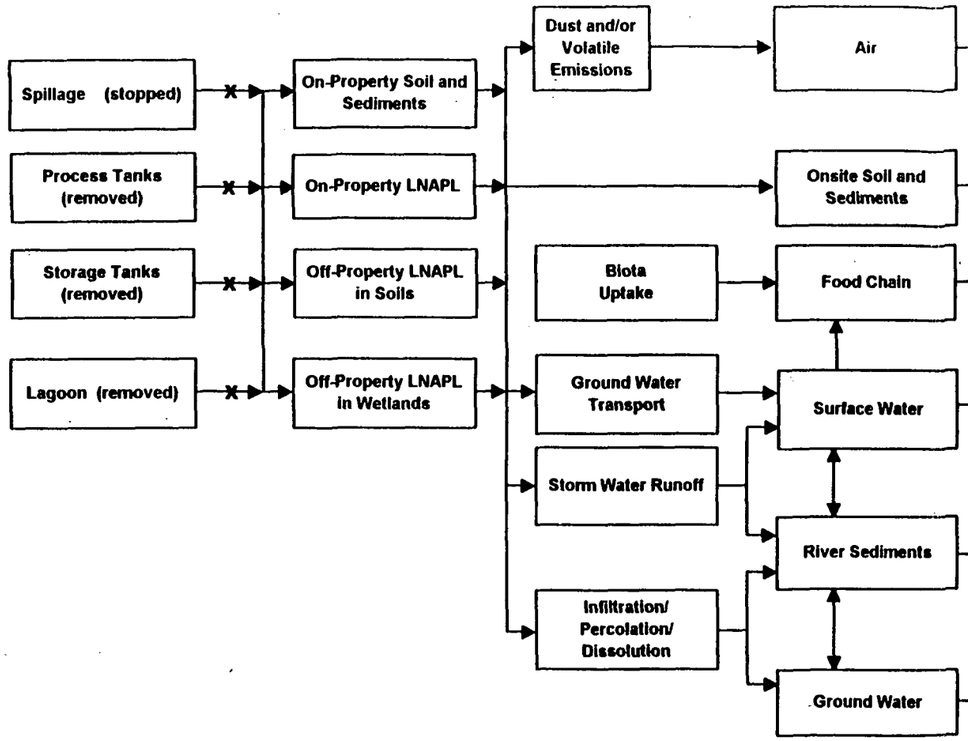


* INTERMEDIATE DEPTH GROUND WATER CONTAINS SITE-RELATED CONSTITUENTS, BUT THEY ARE NOT KNOWN TO DISCHARGE TO SURFACE WATER.

O'BRIEN & GERE ENGINEERS, INC.

FIGURE 29

300879



Potential Receptors		Exposure Routes: Ingestion (a)	Inhalation (b)	Dermal Contact (c)
Occupational	1			
Construction	2			
On-property visitor/tresspasser	3			
Off-property resident	4			
Future onsite resident	5	–	–	–
Terrestrial Biota	6	–	–	–
Occupational	7			
Construction	8			
On-property visitor/tresspasser	9			
Future on-property resident	10	–	–	–
Terrestrial Biota	11	–	–	–
Off-property resident	12			
Future on-property resident	13	–	–	–
Aquatic Biota	14		–	
Terrestrial Biota	15	–	–	–
Occupational	16			
Construction	17			
On-property visitor/tresspasser	18			
Off-property resident/recreational	19			
Future on-property resident	20	–	–	–
Aquatic Biota	21	–	–	–
Occupational	22			
Construction	23			
On-property visitor/tresspasser	24			
Off-property recreational	25			
Future onsite resident	26	–	–	–
Aquatic Biota	27	–	–	–
Occupational	28			
Construction	29			
On-property visitor/tresspasser	30			
Off-property resident	31			
Future onsite resident	32	–	–	–
Terrestrial Biota	33	–	–	–

Notes

1. Justification for selection of relevant exposure pathways is provided in following tables
   - ● = Pathway complete, further evaluation recommended
   - ■ = Receiving media/release mechanism dependent, further evaluation recommended
   - ○ = Pathway evaluated and found incomplete and/or insignificant, no further evaluation recommended
   - □ = Potential exposure evaluated in the air exposure pathway.
   - – = Exposure pathway not relevant or not addressed in human health RA
   - x = Former primary source (removed)
2. Off-property and On-property refer to the definition of the BROS property as specified in the Consent Decree.

Title:

CONCEPTUAL MODEL TO EVALUATE POTENTIAL EXPOSURE PATHWAYS

BRIDGEPORT RENTAL & OIL SERVICE SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 06/23/97	Figure 30
Prepared by: J.R.M.	Scale: N.T.S.	
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301036	

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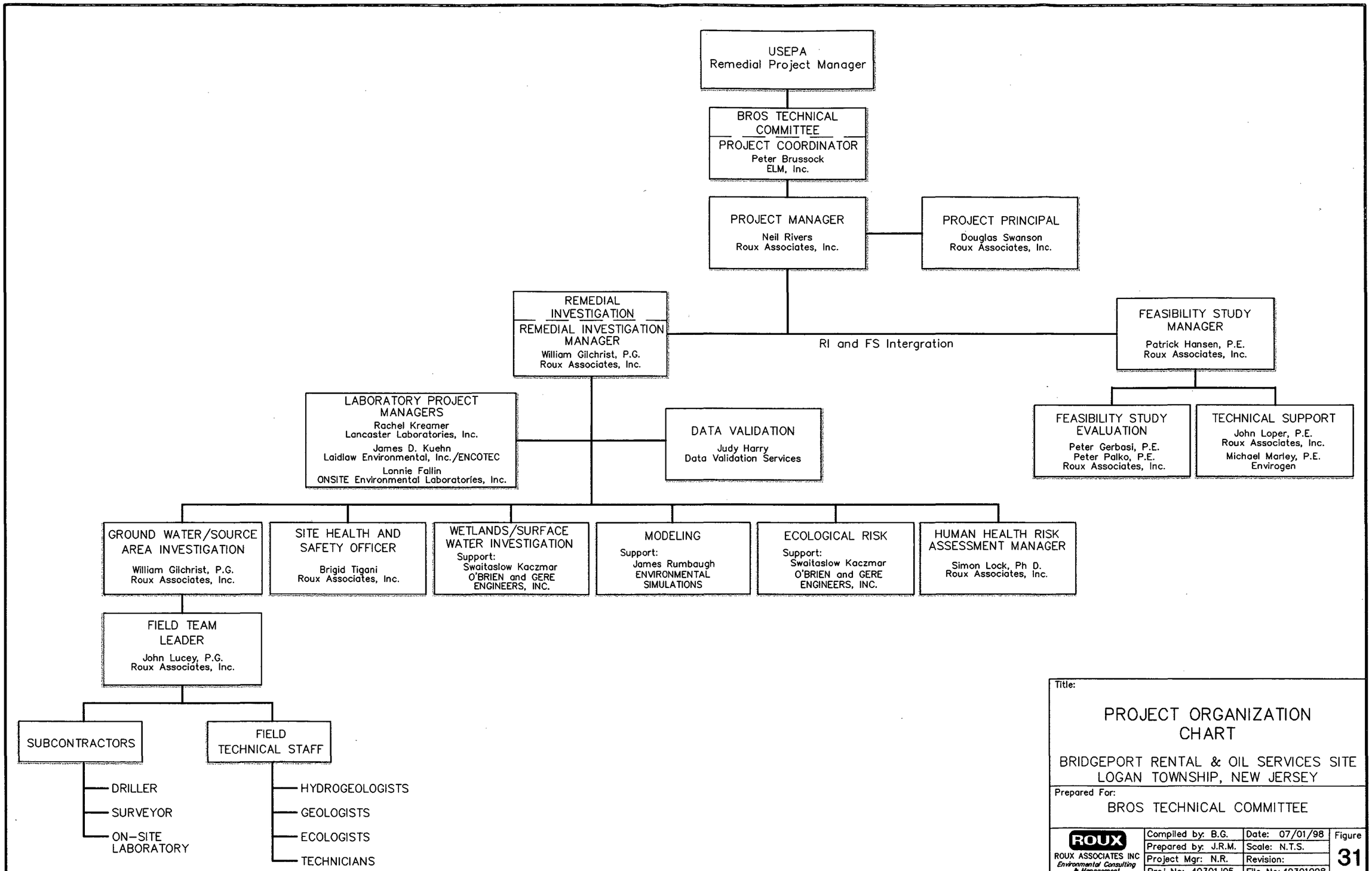

Title:

PROJECT ORGANIZATION CHART

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:
BROS TECHNICAL COMMITTEE

ROUX
ROUX ASSOCIATES INC
Environmental Consulting & Management

Compiled by: B.G.	Date: 07/01/98	Figure
Prepared by: J.R.M.	Scale: N.T.S.	31
Project Mgr: N.R.	Revision:	
Proj No: 49301J05	File No: 49301098	

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PLATES

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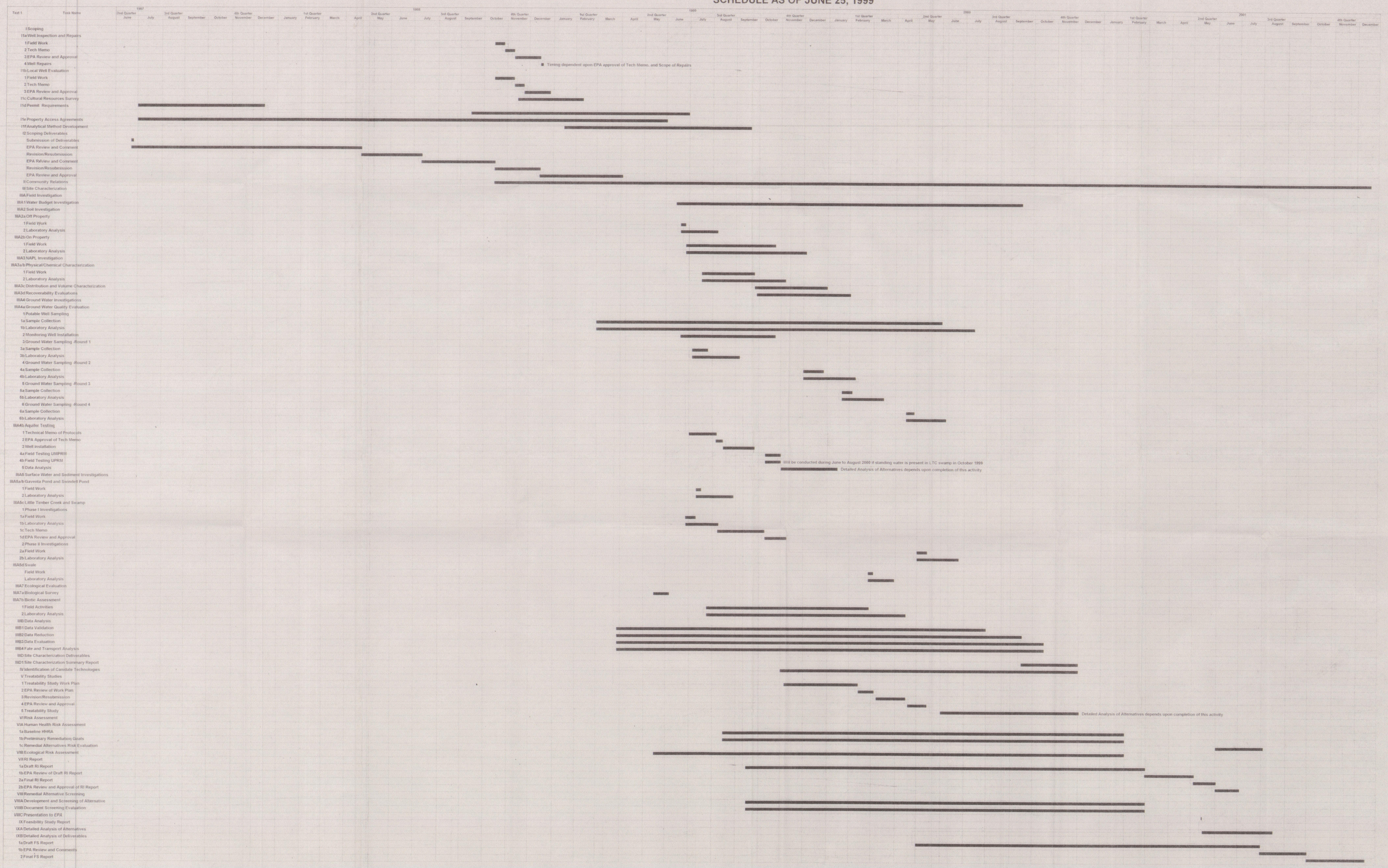
PLATE 1: PHASE 2 RI/FS SCHEDULE

SCHEDULE AS OF JUNE 25, 1999



APPENDICES

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APPENDIX A

EVALUATION OF TECHNICAL IMPRACTICABILITY

Background

Ground water remedial actions under CERCLA have typically included pump and treat technologies. Between 1982 and 1990, 72 percent (i.e. 314) of all Superfund site RODs addressing ground water remediation specified pump-and-treat technology (USEPA, 1994). However, before 1989, the limitations of pump-and-treat technology were not fully known, because most pump-and-treat systems were so new that their long term performance had not been assessed.

Beginning in 1989, the results of several large scale studies of the effectiveness of pump-and-treat systems have been published by the USEPA, other regulatory agencies and private researchers. In September 1989, the USEPA released a study regarding the effectiveness of ground water pump-and-treat systems at 19 sites in the United States and Canada (USEPA, 19891a; 1989b; 1989c). The USEPA study found that although the ground water extraction systems evaluated were able to achieve hydraulic containment of the contaminant plumes, at only 1 of the 19 sites had the aquifers been restored to drinking water standards. The study states "as more experience has been gained with a long term operation of ground water extraction systems, it has become apparent that their performance often does not meet initial expectations. This is particularly true in systems that have been installed with the intention of cleaning up contaminated aquifers to health-based concentration goals. Cases where performance goals for aquifer clean up have been met or exceeded are quite rare."

Additional study conducted by the USEPA and others since the 1989 USEPA studies have confirmed the limited effectiveness of pump-and-treat technologies in restoring ground water quality, especially in complex geological settings and where NAPL is present below the water table.

To address the issue of pump-and-treat practicability, the USEPA issued guidance on evaluating the technical impracticability of groundwater restoration in 1993 (USEPA, 1993). This guidance

was prepared to address the issue of how to determine whether ground water cleanup goals are technically achievable at a particular site, and how to establish an alternative, protective cleanup strategy where restoration is determined to be technically impracticable. This guidance document states that "this guidance does not signal a scaling back of EPA's efforts to restore contaminated ground waters at Superfund sites and RCRA facilities. Rather, EPA is promoting the careful and realistic assessment of the technical capabilities at hand to manage risk posed by ground water contamination. This guidance provides consistent guidelines for reevaluating technical impracticability and for maintaining protectiveness at sites where ground water cannot be restored within a reasonable time frame."

Criteria for a Technical Impracticability Determination

A determination for technical impracticability (TI) is dependent on meeting certain criteria as specified by USEPA. The TI Determination will include the following components, as specified in USEPA Directive No. 9234.2-25, titled *EPA Guidance on Evaluating the Technical Impracticability of Ground Water Restoration* (USEPA, 1993):

1. identification of specific ARARs or media-specific cleanup standards for which a TI waiver is being sought;

2. identification of the spatial area over which the TI Determination will apply (i.e., the TI Zone);

3. a conceptual model that describes site geology, hydrogeology, ground water contamination sources, transport and fate;

4. evaluation of the restoration potential of the site, including;

   - a demonstration that contamination sources have been identified and have been, or will be, removed and contained to the extent practicable;

   - an analysis of the performance of any ongoing or completed remedial actions;

- predictive analysis of the time frames to attain required cleanup levels using available technologies;

5. demonstration that no other remedial technologies (conventional or innovative) could attain cleanup levels within a reasonable time frame;

6. estimates of the costs of existing or proposed remedy options; and

7. any additional information that is deemed relevant for the Determination.

In general, the first three components will be addressed during the RI and the four components will be evaluated during the FS. Based upon our current understanding of site conditions, components 2 through 4 are inherently dependent upon the site-specific factors presented in the conceptual model and are most dependent upon completion of the RI scope of work outlined in Tasks 1 through 7.

Application of TI at the BROS site

The presence of LNAPL within the lagoon residuals and various locations throughout the site has been reported by USEPA. Most of the residual LNAPL appears to be located in a ring around the north side of the lagoon. The stratigraphic units are heterogeneous, and include fill materials surrounding the former lagoon, backfill, and the silt and clay layer between the Upper PRM and Upper Middle PRM aquifers. Especially significant is the finding in the Phase 3 soil work of significant LNAPL trapped below the current water table in this area. CH2M Hill also reported some LNAPL below the former lagoon.

As such, pump-and-treat technologies will be likely have limited effectiveness; a problem compounded by the likelihood of preferential flow paths through adjacent higher permeability strata. Complete recovery or excavation of the LNAPL is not likely practicable, given its apparent distribution.

The following factors summarize the reasons why a TI Determination is an appropriate consideration for the BROS site.

1. Complex Hydrogeology

   Due to the complex interactions between ground water and surface water, a pump and treat scenario will probably be inefficient and ineffective at restoring to drinking water standards. Other potential problems include potential dewatering of the adjacent wetlands and pulling in the CLTL site plume towards the BROS property due to the high flow rates necessary to overcome the surface water/ground water interactions.

2. LNAPL - Although the presence of DNAPL is not supported by the available data, Roux Associates, Inc.'s interpretation of available data is that residual LNAPL material exists in the peat layer/mud wave. The likely presence and extent of this LNAPL will severely limit ground water restoration in the vicinity of the former lagoon. The nature and extent of LNAPL, coupled with the hydrogeologic complexities, would result in the site being characterized as "the most difficult to remediate" category, according to USEPA guidance (USEPA, 1996).

3. Source Removal - Source removal actions have taken place at the site, resulting in substantial mass reduction of oil-based material. Further, Roux Associates, Inc. predicts the residual material in the mud wave is relatively immobile due to degradation over time, a high organic carbon content in the mud wave strata, the presence of a relatively low permeability layer below the peat layer, the characteristics of the waste oil, and the removal of the elevated hydraulic head in the former lagoon.

4. Adverse Impacts of a Pump and Treat System - Additional pumping from off-site areas or deeper aquifer zones can have an adverse impact. These systems would potentially spread contaminants outward, downward and towards the wetlands. Further, excessive pumping can dewater the wetlands–with attendant ecological impacts, especially during the summer and drought conditions.

5. <u>In-Situ Treatment Alternatives and Natural Attenuation of Contaminants</u> - Existing and supplemental data will be used to evaluate the effectiveness of in-situ treatment alternatives in combination with natural attenuation and if supported, to develop remedial alternatives for ground water in the Upper and Upper Middle PRM aquifer that will be compared with the presumptive pump-and-treat remedial approach.

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B

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APPENDIX B

CURRENT STATUS OF PUMP AND TREAT TECHNOLOGIES FOR GROUND WATER REMEDIATION

Ground water "pump-and-treat" has been the most widely used technology for remediating impacted ground water at sites throughout the United States. Between 1982 and 1990, 72 percent (i.e., 314) of all Superfund site Records of Decision (RODs) addressing ground water remediation specified pump-and-treat technology (USEPA, 1994). However, before 1989, the limitations of pump-and-treat technology were not fully known, because most pump-and-treat systems were so new that their long term performance had not been assessed.

Since 1989, the results of several large scale studies of the effectiveness of pump-and-treat systems have been published by the USEPA, other regulatory agencies and private researchers. In September 1989, the USEPA released a study regarding the effectiveness of ground water pump-and-treat systems at 19 sites in the United States and Canada (USEPA, 1989a; 1989b; 1989c). The USEPA study found that although the ground water extraction systems evaluated were able to achieve hydraulic containment of the contaminant plumes, at only 1 of the 19 sites had the aquifers been restored to drinking water standards. The study specifically states "as more experience has been gained with a long term operation of ground water extraction systems, it has become apparent that their performance often does not meet initial expectations. This is particularly true in systems that have been installed with the intention of cleaning up contaminated aquifers to health-based concentration goals. Cases where performance goals for aquifer cleanup have been met or exceeded are quite rare."

In 1991, the USEPA reevaluated the performance of pump-and-treat systems at these 19 sites, based upon updated performance data, and reviewed case histories of five additional sites (USEPA, 1992a; 1992b). The USEPA found that pump-and-treat systems achieved site-specific cleanup goals at only 1 of the 24 sites evaluated.

In March 1990, the USEPA issued guidance to determine when, where, and how pump-and-treat technology can be used successfully to contain and/or remediate contaminant plumes (USEPA,

1990). The USEPA guidance document states that "the main limitation of pump-and-treat technology is the long time that may be required to achieve an acceptable level of cleanup." Actual aquifer cleanup times are often substantially longer than initial aquifer cleanup time estimates in part due to the "tailing" effect often observed with ground water extraction. Tailing is the asymptotic decrease of contaminant concentrations in water that is removed in the cleanup process. Tailing effects result in longer pumping times and greater volumes pumped to reach a specific cleanup concentration goal. Tailing may be caused by several phenomenon, including aquifer heterogeneities, and sorption/desorption of constituents of concern in the aquifer (USEPA, 1990).

Based upon the results of the USEPA 1989 (USEPA, 1989a, 1989b, 1989c) and 1992 (USEPA, 1992a, 1992b) studies, the USEPA Office of Solid Waste and Emergency Response (OSWER) updated USEPA policy concerning remediation of impacted ground water at both Superfund sites and RCRA facilities (USEPA, 1992c). Early or interim actions recommended in this USEPA Directive include:

- contain the plume early;
- extract free-phase non-aqueous phase liquid (NAPL) early, where possible;
- initiation of early action should take place as soon as possible after a problem is identified that either requires an expeditious response or for which an early action is appropriate; and
- early or interim action should be appropriately documented.

This Directive also provides recommendations on restoring ground water quality, to the extend practicable, after a final remedy has been selected. These include:

- remedial action/measures for impacted ground water should generally be implemented in a phased approach;

- ground water remedial action should be designed to include careful monitoring and provisions for modification over time to improve their effectiveness and efficiency;

- after a ground water remedy is implemented, modification of remedial objectives may be warranted where cleanup standards cannot be achieved due to technical impracticability from an engineering perspective;

- USEPA will make its determination on whether or not aquifer restoration to cleanup standards is technically impracticable for a given site based on USEPA approved data, supporting analysis and site characterization which justifies such a determination; and

- if a determination of technical impracticability is made, USEPA will also determine alternative remedial action objectives which protect human health in the environment and are appropriate, based on site conditions.

The Directive states "these evaluations [USEPA's 1989 and 1992 studies] identified hydrogeologic and contaminant characteristics as well as system design factors that may impede the ability of extraction systems to achieve appropriate cleanup levels over the entire area of contamination. These characteristics, listed below, are probably more common at hazardous waste sites than previously realized and should be considered during site characterization and conceptual model development.

- hydrogeologic factors: such as significant subsurface heterogeneity, numerous low permeability layers, fractures or karst aquifers, or other hydrogeologic complexities.

- containment factors: such as continued leaching of contaminants from source areas, partitioning of contaminants between ground water and soils, or presence of NAPL [non-aqueous phase liquid] in the subsurface.

- system design factors; such as poorly designed or improbably located extraction wells or inefficient pumping schemes."

Recently, the National Research Council (NRC) released a comprehensive study (NRC, 1994) analyzing the major technical and public policy issues arising from the technical limits to aquifer remediation. This study was funded by USEPA, the Department of Energy, the Coalition on Superfund, and Chevron Corporation. This study consisted of hearing presentations from numerous private and public groups on all aspects of ground water and soil remediation, including USEPA's Office of Solid Waste and Emergency Response, technical specialists from USEPA's Ada, Oklahoma ground water research laboratory, researchers working at DOE facilities; industry trade groups, consultants, contractors, impacted parties; and environmental groups. Additionally, the study reviewed data from approximately 80 sites where pump-and-treat systems have been installed.

This report states "the exact number of pump-and-treat systems currently in operation in the United States is unknown, but it may well exceed 3,000. A sufficient history of this operation of this technology now exists to assess its efficacy. Unfortunately, and some would say not surprisingly, the effectiveness of this technology to restore contaminated aquifers seems quite limited. This has led to a widely-held view that pump-and-treat is a failed technology and should be rejected as a technique for ground water remediation. Thus, the United States and other industrialized nations, as well as developing nations, are confronted with a major dilemma; how to protect human health and the environment from contaminated ground water without wasting resources pursuing technical strategies that appear unable to achieve agreed-upon societal goals. A further significant problem is how to convey these technical limitations to a public that has grown increasingly skeptical of technologists."

A key component of this study was an evaluation of the performance of *ground water* pump-and-treat systems. The study found that at the majority of impacted sites, the complex properties of the subsurface environment and the complex behavior in the subsurface interfere with the ability of conventional pump-and-treat systems to achieve drinking water standards for impacted ground water. Of the 77 sites evaluated where pump-and-treat systems are operating, 69 of the sites have not achieved cleanup goals. The study concluded that remediation by pump-and-treat systems is a slow process, and that estimating the time to achieve cleanup goals is difficult and is subject to a

large number of uncertainties. Moreover, the study concluded that typical methods used to calculate cleanup times often result in underestimates because they neglect processes that can add years, decades or even centuries to the cleanup. Specific conclusions regarding the performance of conventional pump-and-treat systems provided in the NRC study are included below:

- "At some sites with simple geology and dissolved contaminants, pump-and-treat systems appear to be capable of cleaning up ground water to health-based standards in a relatively short item. Such simple sites are the exception rather than the rule.

  Nevertheless, the committee found examples of sites where pump-and-treat systems achieved health-based cleanup goals for one or more contaminants. At such sties, it is important to recognize that continued monitoring is necessary to verify the long-term effectiveness of the cleanup. Contaminants may remain attached to solid materials or stored in nonaqueous phases in the subsurface even when ground water from monitoring wells meets regulatory standards.

- At many of the sites where pump-and-treat systems have attained cleanup goals, the contaminants of concern are readily biodegradable. Pump-and-treat systems have achieved health-based goals at sites contaminated with gasoline, sites where contaminants are fully dissolved, and sites with both dissolved and LNAPL plumes (where the source has been removed) in shallow aquifers. The success of pump-and-treat systems at these sites may in part be due to biodegradation processes that convert contaminants to nontoxic products.

- The chemical nature of contaminants can prevent pump-and-treat systems from restoring aquifers to health-based standards in a relatively short time. Pump-and-treat systems cannot restore aquifers except over very long time periods (hundreds or thousands of years) where NAPL contaminants remain unless the NAPLs are contained or removed. For contaminants that strongly sorb to solid materials in the subsurface, cleanup times using pump-and-treat systems may also be very long.

- The geologic conditions of the site can prevent pump-and-treat systems from restoring aquifers to health-based standards in a relatively short time. Clay lenses and other heterogeneities, fractured bedrock, and zones of low hydraulic conductivity can trap contaminants and prevent the large-scale water circulation necessary for effective flushing of the subsurface.

- At sites where complete aquifer restoration to health-based standards is impossible or impractical due to the chemical nature of the contaminants or geologic complexity, pump-and-treat systems can prevent the contamination from spreading and can cleanup or shrink the dissolved portion of the contaminant plume. Pump-and-treat systems can prevent contaminant migration by establishing a hydraulic barrier around the site. They can shrink the contaminant plume by pumping out contaminated water, which is then replaced at the outer edges of the plume with clean water. These accomplishment reduce the risk posed by the contamination by minimizing the area affected by the contamination.

- Cleanup times for pump-and-treat systems vary widely depending on site conditions and pumping rates. For small sites with simple geology and dissolved contaminants, cleanup times may be relatively short, on the order of years. The presence of geologic heterogeneities, nonaqueous-phase contaminants, sorbed contaminants, and contaminant sources above the water table can extend cleanup times by anywhere from a few years to thousands of years and can make predicting the time highly uncertain. Because cleanup time also depends on the pumping rate (which system operators can control), evaluations of cleanup time should consider the number of pore volumes of ground water that must be extracted to achieve cleanup, in addition to the estimated cleanup time.

- The operation of pump-and-treat systems should be viewed as a long-term project, in which the system's design is modified in response to improve understanding of the site. Because of the complexity of the contaminated subsurface, the performance of a pump-and-treat system will not always be certain until the system is tested by beginning the

cleanup. Monitoring provides the information necessary to optimize the system's performance and ultimately determine whether it will be able to reach cleanup goals."

In summary, within the past several years, studies of pump-and-treat systems indicate that cleanup goals may be essentially impossible to achieve in a reasonable time frame at most sites. Based upon this information USEPA has included these concepts in their *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA* Sites (USEPA, 1996). This updated policy now considers the limitations of pump-and-treat systems to achieve cleanup goals and allows for alternate remedial approaches, including natural attenuation as a component of a remedial strategy.

Application of Pump-and-Treat at the BROS Site

Based upon the heterogeneous nature of the Upper PRM aquifer, the complex ground water/surface water interactions, the proximity to wetlands, and the contaminant types and their concentrations in ground water; it is improbable that extraction and treatment of ground water will achieve health-based concentration goals cost-effectively or in a reasonable time frame, as supported by the above-referenced studies.

Rather than focus on a pump-and-treat system, a more diversified set of remedial alternatives will be considered in combination with policy options, such as technical impracticability determinations and alternate concentration limits. Recovery of LNAPL where appropriate, and evaluation and application of the principles of intrinsic remediation to address the ground water contamination at the BROS site will be the concurrent focus in early remedial alternative evaluations. In addition, the evaluation of alternatives will also determine if varying remedial approaches are appropriate for the shallow and deeper strata, as well as, near source areas and downgradient of source areas. At the same time, Roux Associates, Inc. recognizes the importance of source control (e.g., if LNAPL dissolution is a significant factor) and notes that pump-and-treat elements for these purposes will be evaluated as a component of a flexible and phased remedial strategy.

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APPENDIX C
NATURAL ATTENUATION

Natural attenuation has been recognized by EPA as a viable component of cleanup for at least seven years (NCP, 1990). More recently, the overall importance of natural attenuation in ground water restoration has gained much attention and acceptance. At least 17 RODs have been issued in the United States with natural attenuation listed as a component of the selected remedy for each site and other RODs are being reevaluated to include a natural attenuation component. Of these 17 Superfund RODs, all concern remediation of ground water contaminated with either organics or metals, or both, and most select capping or source-removal coupled with natural attenuation, institutional controls, and ground-water monitoring. The USEPA's *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites* (USEPA, 1996) and proposed rulemaking (May 1, 1996 Federal Register 19431-19464) recognize the validity and importance of natural attenuation in achieving remedial objectives. The body of information on natural attenuation continues to grow. Significant focus has been placed on natural attenuation of chlorinated compounds due to their presence at many sites. Two documents which focus on natural attenuation of chlorinated compounds are the *Guidance Handbook on Natural Attenuation of Chlorinated Solvents* developed by a consortium of the USEPA and private sector companies (RTDF, 1996) and the *Overview of the Technical Protocol for Natural Attenuation of Chlorinated Aliphatic Hydrocarbons in Ground Water Under Development for the U.S. Air Force Center for Environmental Excellence* (USEPA, 1996) prepared jointly by the USEPA, the U.S. Air Force and the private sector.

For nearly ten years, the NJDEP has recognized that under certain conditions, natural systems can remediate themselves after the source is removed or controlled. Natural remediation has been approved by the NJDEP at numerous sites where contamination of hydrocarbons has occurred and active remediation such as pump-and-treat was not practical. The recently promulgated amendments to NJDEP's Technical Requirements for Site Remediation (N.J.A.C. 7:26E) outline the procedures for the evaluation and application of natural attenuation as a remedial approach.

Mechanics Associated with Natural Attenuation

The commonly accepted processes that contribute to natural attenuation of hydrocarbons and chlorinated solvents include:

Degradation: The degradation of most hydrocarbons and chlorinated solvents in ground water occurs by oxidation-reduction reactions that are predominantly mediated by microorganisms in the environment. These are referred to as biodegradation reactions. Some chlorinated solvents may also degrade through abiotic (chemical) reactions that are mediated by metals (e.g., iron and iron-complexes) or by water (e.g., hydrolysis reactions).

Advection, Dispersion and Dilution: Advection is defined as the movement of molecules dissolved in water along the ground water flow path at an average velocity. During advection, molecules will also spread along and away from the expected ground water flow path due to processes at the molecular level. This process is called dispersion and is related to the type of geology and its influence on the path of a chemical around particles in the subsurface. The combined processes of advection and dispersion result in a net decrease of the contaminant concentrations in ground water, under both pumping and non-pumping conditions.

Diffusion: Diffusion is a dispersive process that results from the movement of molecules along a concentration gradient. Molecules move from areas of high concentration to low concentration, independent of ground water flow direction.

Sorption/Desorption: Molecules can adsorb onto and in some cases be absorbed by geologic materials. Over time, many of these molecules will desorb from the geologic materials (organic and inorganic) in response to changing concentration gradients. Sorption decreases the advective rate of molecules dissolved in ground water.

Volatilization: Transfer of a molecule from an aqueous solution to the vapor phase (phase transfer) is termed volatilization. Many hydrocarbons and all chlorinated solvents are volatile compounds that partition between aqueous and gas phases, with the less-chlorinated compounds having a tendency towards higher volatility. Volatilization may contribute to natural attenuation

through the transfer of VOCs from ground water to the vadose zone or to the atmosphere during discharge.

Stabilization and Sequestration: Stabilization and sequestration are processes whereby chemical molecules become chemically bound by a stabilizing agent (e.g., clay, humic materials), reducing the mobility of the molecule in the ground water.

Enhancements to Natural Attenuation

Natural attenuation processes be enhanced, primarily through the stimulation of biodegradation processes. These processes are typically enhanced through the addition of nutrients that support increased microbial growth. Specific amendments are selected based upon the preferred microorganisms, degradation pathways and constituents of concern for the site. For example, oxygen addition is commonly applied where petroleum hydrocarbons are a concern, as aerobic biodegradation is the most rapid process. For some chlorinated organics, methanotrophic oxidation is the dominant biological degradation pathway. In these instances, introduction of methane may be appropriate, if not already present as a result of hydrocarbon degradation. The specific amendments and application methods can be developed through treatability studies.

Application of Natural Attenuation at the BROS Site

The primary constituents of concern for the BROS site are amenable to natural attenuation, especially those that have been transported from the source areas. The petroleum hydrocarbons (aromatic, aliphatic and polynuclear aromatic) are amenable to aerobic biodegradation and, especially for the higher molecular weight compounds, adsorption. Chlorinated VOCs are amenable to both direct mineralization and cometabolism. Direct mineralization has been demonstrated for vinyl chloride, dichloromethane and chloroethane (RTDF, 1996). Anaerobic and aerobic cometabolism are important processes for the degradation of such chlorinated aliphatics as PCE, TCE, and DCE.

Based largely on the impracticability of active remedial measures to achieve NJDEP ground water quality criteria or established MCLs, natural attenuation will likely play a major role in the remedial decision making process at BROS, probably in combination with in situ treatment approaches that also enhance the natural attenuation process. Natural attenuation is an

appropriate remedial technology, and is likely to achieve remedial action objectives in a time period consistent with that of more aggressive remedies because:

- source control/containment measures previously conducted will substantially reduce and prevent further release of constituents to downgradient areas;

- these source control/containment measure at the site will result in diminishing ground-water concentrations within the downgradient areas over time, as the mass of constituents releases to ground water has decreased;

- the extent of the downgradient dissolved constituent plumes in the Upper and Upper Middle PRM aquifers is limited and is not known to be currently impacting any potable water sources; and

- the VOC distribution within the Upper PRM is largely contained by surface-water discharge boundaries.

Much of the published work to date on natural attenuation has focused on contamination at several U.S. Air Force sites located across the country. The Guidance Handbook (RTDF, 1996) has been published outlining a technical protocol for implementing natural attenuation with long-term monitoring for natural attenuation in ground water and was a primary source of guidance for the development of natural attenuation assessment methodologies at for the RI scope of work. In essence, this guidance outlines the methods to demonstrate that natural attenuation is actually occurring within the aquifer at a given site, and provides the framework for monitoring the performance of a natural attenuation system, similar to monitoring the performance of any remedial system selected to remedy a ground-water plume. Relevant NJDEP guidance has also be considered.

Based on the natural attenuation evaluation in the Phase 2 RI, the potential advantages and disadvantages of natural attenuation at the BROS Site will be compiled and compared with other remedial approaches and components, including consideration of remedial time frames and identification of possible contingency remedies.

REFERENCES

NJDEP, 1997. *Technical Requirements for Site Remediation.* N.J.A.C. 7:26E.

Remedial Technologies Development Forum (RTDF) *Guidance Handbook on Natural Attenuation of Chlorinated Solvents.* Draft, September 1996.

USEPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERLA Sites.*

Weidemeier, T.H., Swanson, M.A., Moutoux, D.E., Wilson, J.T., Kampbell, D.H., Hansen, J.E., and Haas, P. *Overview of Technical Protocol for Natural Attenuation of Chlorinated Aliphatic Hydrocarbons in Ground Water Under Development for the U.S. Air Force Center for Environmental Excellence.* United States Environmental Protection Agency, Office of Research and Development, EPA/540/R-96/509, September 1996.

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Document Submission Sheet

Amendment to the Workplan Scope of Work for the Stage IB and Supplementary Stage IA Cultural Resources Surveys at the BROS Superfund Site

Roux Associates, Inc. has been contracted by the BROS Technical Committee, and thereby, as an authorized representative of the Settling Defendants, submits this draft document in compliance with the BROS Consent Decree and the USEPA's August 6, 1997 letter to the Project Coordinator for the Settling Defendants.

Neil R. Rivers
Phase 2 RI/FS Project Manager
(Signed as per Paragraph 69 of the BROS Consent Decree)

c: Distribution List

AMENDMENT TO THE WORKPLAN SCOPE OF WORK FOR STAGE IB AND SUPPLEMENTARY STAGE IA CULTURAL RESOURCE SURVEYS AT THE BROS SUPERFUND SITE, LOGAN TOWNSHIP, GLOUCESTER COUNTY, NEW JERSEY

February 13, 1998

Prepared for:

ROUX ASSOCIATES, INC.
1222 Forest Parkway, Suite 190
West Deptford, New Jersey 08066

Prepared by:

Hunter Research, Inc
120 West State Street,
Trenton, NJ 08608

300909

BS49301J.129

A. Understanding of Project and Introduction

As per the request of USEPA (August 6, 1997 letter) Hunter Research Inc., developed a more detailed Scope of Work for a Stage IB and expanded Stage IA Cultural Resource Survey on and around the BROS Superfund Site in Bridgeport, Gloucester County, New Jersey. The scope is based on materials supplied by Roux Associates on August 29th 1997 (including the February 1992 Stage IA "Historical Archaeological Survey" by Louis Berger & Associates Inc.), general familiarity with the project area and with Superfund cleanup operations, and discussions with the staff of Roux Associates.

A Cultural Resource Survey is called for as part of requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), entailing the cleanup of the Superfund (NPL) sites. Pursuant to the BROS Consent Decree, a Stage IB Cultural Resource Survey (CRS) is required as part of the Phase 2 Remedial Investigation Feasibility Study (RI/FS). In addition, the Stage IA survey must be expanded to include the entire site as described in the Work Plan.

Levels of effort presented in this scope of work are based on the assumption that field inspection, preliminary investigation of any standing structures, shovel testing, soil screening and artifact processing will not expose field personnel to hazards which will require any special personal protection equipment.

The cultural resource survey work will be undertaken with reference to the New Jersey Historic Preservation Office Guidelines for Archaeological Investigations: Identification of Archaeological Resources (January 17, 1996). This document presents recommended practice for such surveys in New Jersey, and allows for a variety of approaches provided that these are made specified and achieve the objectives for Stage I identification surveys. The specific methodology adopted for this study is presented in Section C below.

B. Cultural Resource Issues

A Phase IA Historical Archaeological Survey (a.k.a. Stage IA CRS) was prepared in February 1992 by Louis Berger & Associates, Inc. (LBA). The area of the LBA study was limited to the area between Routes 295 and 130 with a small portion investigated between Routes 130 and 44 (Figure 1).

The LBA survey defined three areas of relatively high archaeological potential, totaling about 25 acres, where historic and prehistoric archaeological resources might be present, the former related to two extant building complexes (Figure 2). The areas are:

1. The area around the Keller farmstead, which is the area of the peach orchard and associated buildings;

2. The northern portion of the study area which is the area in the vicinity of the southbound Route 130 off ramp to Cedar Swamp Road (otherwise known as the Starr property); and

3. The area immediately to the north of the BROS property between Cedar Swamp Road and Route 130, which is the current Foster Wheeler equipment yard.

All three areas were characterized by LBA to have high archaeological sensitivity for prehistoric resources. Both the Keller Farmstead and the northern portion of the study area were considered to have high potential for historic archaeological resources due to the age of the structures in the area. LBA identified the Keller farmhouse and associated out buildings as dating from the latter half of the nineteenth century. Two structures in the northern portion of the study area may date from the turn of the century according to LBA. The remaining areas in the LBA study were characterized as of low potential because of the extent of major disturbance on the rest of the study area, and were excluded from further consideration.

Some of the currently proposed field activities to be performed as part of the Phase 2 RI/FS occur outside of the area in which the LBA Stage IA CRS addressed. In these areas a Stage IA CRS will be carried out concurrently with the Stage IB on the areas defined in the LBA study. The potential for cultural resources in the additional area identified for Stage IA survey is unknown, although its proximity to Little Timber Creek suggests that non-wetland areas may have prehistoric potential. Initial assessments will also be made of any standing buildings encountered as well as below ground (archaeological) resources.

C. Project Tasks and Methodology

Background Research

Limited background research beyond that already undertaken for the earlier Stage IA project will be undertaken. Preliminary review of historic maps suggests that one farmstead site may lie in the additional area to be subjected to Stage IA investigations. Historic maps and secondary sources will be examined, and the site files of the New Jersey State Museum and State Historic Preservation Office will be reviewed for post-1992 surveys and site discoveries.

Site Safety Plan

Hunter Research Inc. will be provided with documentation on the nature of the hazards and a copy of the Roux Associates, Inc. Site Specific Health and Safety/Contingency Plan (HSCP) and will be also provided with technical advice and clarification.

On the basis of this information, Hunter Research Inc. will prepare any necessary project-specific amendments to the Roux Associates, Inc. HSCP in accordance with 26 CFR 1910.120: Hazardous Waste Operations and Emergency Response Section 120 (b). Personnel working on the project will meet qualifications are set out under Section 120 (e) (5).

Field Investigations

Following completion of the background research and the HSCP, field investigations will commence. Roux Associates, Inc. will provide a topographic survey of the project area (AutoCADR12 or earlier-readable digital format preferred), onto which archaeological detail can be mapped.

Stage IA Survey

Hunter Research Inc. estimated that a walkover survey of the additional areas can be completed in one day by two qualified archaeologists. The area will be systematically walked (where feasible), the topography, exposed soils, vegetation and other relevant environmental characteristics documented, specific areas of potential defined in the background research examined in detail, their sensitivity mapped, and any standing buildings noted. A brief investigation will also be completed by an Architectural Historian. The following specific tasks will be undertaken:

1. A thorough literature and map search and review from documents available from the State Historic Preservation Office and the New Jersey State Museum, plus various local, county, and state organizations, repositories, and record centers;

2. Interviews with individuals knowledgeable about history and prehistory of the study area;

3. A general analysis of the environmental and geological conditions of the study area with an evaluation of the gathered documentary sources to determine the probability that prehistoric and historic cultural resources exist;

4. A visual inspection of the study area by an archaeologist to evaluate current conditions and to access the extent to which prior activities on the property may have disturbed areas of cultural resources sensitivity;

5. Visual inspection of the study area by an architectural historian to identify all buildings 50 years or older;

6. An evaluation of the possible impacts of planned activities on areas of suspected cultural sensitivity; and

7. Determination of the need to complete a Stage IB CRS in the additional area.

Stage IB Survey

The purpose of this part of the survey is to locate all possible cultural resources in the areas of the LBA Stage IA CRS identified as having high archaeological potential. Typically, Stage IB investigation of areas of archaeological potential is through the excavation of shovel tests spaced at an average of 17 per acre. On this project a combination of systematic surface collection and broad interval shovel testing and judgementally-placed tests will be employed. This approach is appropriate for the following reasons:

1. Historic cultivation of the area has probably reduced the integrity of any prehistoric resources, which will therefore be found chiefly in the plowzone. Wide-spaced testing will test this assumption by examining the full stratigraphic profile in different parts of the project area and document the vertical distribution of artifacts within it. The surface collection strategy will be more effective than shovel testing in locating small prehistoric artifact scatters in plowzone contexts, and the two approaches are therefore complementary.

2. Historic archaeological resources are likely to consist of sheet trash related to the historic farmsteads. This material can be adequately characterized through a surface collection strategy.

3. Soil visibility is good in the area around the Keller Farmstead. A surface collection strategy minimizes contact with potentially contaminated soils.

The hand-dug shovel test pits which will be performed during the Stage IB CRS will consist of the following activities:

- Removal of the grass;
- Careful excavation, using hand tools, of an area typically 1½ feet square to a depth between 2 and 3 feet below ground surface;
- Screening of the soil removed through ¼-inch hardware cloth;
- Recording of soils using Munsell designations texture, wetness, and composition and general artifact descriptions, if pertinent; and
- Restoration of the area to its original contour (compacting soil as it is replaced) and replace the grass removed initially.

Artifacts which are found will either be described in the field and left in the field or will be labeled, bagged and retained for laboratory examination. Artifacts will be classified according to chronology, cultural affiliation, technology and function. Artifact analysis will follow the guidelines of the New Jersey State Museum.

The Stage IB CRS inspection and shovel test pits will be performed by Hunter Research Inc. personnel under the supervision of Roux Associates, Inc. The shovel test pits will be performed in accordance with the Site Specific Health and Safety/Contingency Plan using level D personal protective equipment (PPE) under the guidance of a Roux Associates, Inc. site health and safety officer. The soil will be field screened for volatile organic compounds (VOCs) using a photoionization detector (PID).

Site inspection indicates that area around the Starr property is largely inaccessible for testing, being largely covered by debris and apparently disturbed. Therefore, a maximum of 10 tests is proposed here to document soil preservation and the presence or absence of cultural resources. The parking area north of the Keller Farmstead (the Foster Wheeler equipment yard) is similarly inaccessible because of vehicles and debris. Compaction of underlying deposits is also considered to have destroyed the integrity of any underlying resources at this location. No more than five tests will be undertaken at this location, and testing will not be pursued if the initial tests confirm the disturbance on the property has destroyed the integrity of any artifacts that may have been present.

Extensive testing or surface collection is possible only in the area around the Keller Farmstead (Figure 2). Because of the more than 50% visibility in the area of the peach orchard which surrounds the site, a surface collection strategy is therefore considered optimal for Stage IB work in this area. This will be supplemented by up to 40 shovel tests along the northwest side of the Keller Farmstead property adjacent to the wetland area, where a high probability for prehistoric remains is predicted, and elsewhere where additional information on soil profiles is considered appropriate.

Analysis and Report

Following completion of the field survey, a report will be prepared by Hunter Research Inc. which will fully meet the standards and requirements of the New Jersey State Historic Preservation Office (NJSHPO). This report will be prepared in the form of a Technical Memorandum for submission to the USEPA. The report will be a full and concise description and analysis of the work and results. If the results of proposed Stage IA and IB CRS activities described above warrant expansion of cultural resource analysis, the Technical Memorandum will present the scope of proposed supplemental Stage IB activities.

Artifacts and Records

The artifacts from the project are the legal property of the property owner. Disposition of the artifacts is not included in this proposal. The owner will be invited to donate them to the New Jersey State Museum following any decontaminating, if necessary.

D. Company Qualifications and Experience

Hunter Research is a historic resource consulting firm offering a full range of cultural resource management professional services to public and private clients throughout the Mid-Atlantic and Northeast United States. Services offered in-house include historical and archival research, prehistoric, historic and industrial archaeological investigation, historic architectural survey and evaluation, and historic resource management planning.

Both the project manager and the principal investigator for the project will have qualifications that exceed those defined in the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation (Federal Register 48:190, September 29 1983). Resumes for these individuals are attached.

Hazardous Waste Project Experience

The Company has successfully completed a number of projects on NPL sites, most recently Data Recovery operations the Derewal Chemical Company Site in Hunterdon County, New Jersey, and at the Vineland Chemical Company site in Cumberland County, New Jersey. Both projects were performed for the Philadelphia District, U.S. Army Corps of Engineers, and have been fully reported. Hunter Research maintains a core of staff with current 40-hour HAZWOPER and 8-hour HAZWOPER Supervisory certification.

Through a well-developed network of subconsultants, the firm can also provide expertise in related fields, such as underwater archaeology, geomorphology, remote sensing, materials

conservation, and museum display. Founded in 1986, the firm has an established reputation for handling complex cultural resource issues and related regulatory matters in a responsible and timely manner. We seek to be sensitive both to client needs and to our shared heritage.

The corporate headquarters are in Trenton, New Jersey. Satellite offices are maintained in Townsend, Delaware and Wadhams, New York. Full-time staff currently range between 40 and 45 individuals distributed among these three offices.

Hunter Research is a member of ACRA (American Cultural Resources Association), and many of its senior staff members are members of SOPA (Society of Professional Archaeologists).
Hunter Research typically provides historical resource consulting services in connection with:

I. transportation planning (e.g., new highway construction; highway widening and intersection improvements; bridge replacement projects; railroad improvements)water resources planning (e.g., reservoir construction, flood control projects, canal rehabilitation)utilities planning and installation (e.g., transmission line and pipeline projects; sanitary sewers and storm drains)

II. urban redevelopment (mixed-use redevelopment projects in urban settings involving commercial, industrial, transportation and residential land uses)

III. private and public residential development in rural, suburban and urban contexts

IV. recreational planning (federal, state, county and municipal parks; historic sites development)

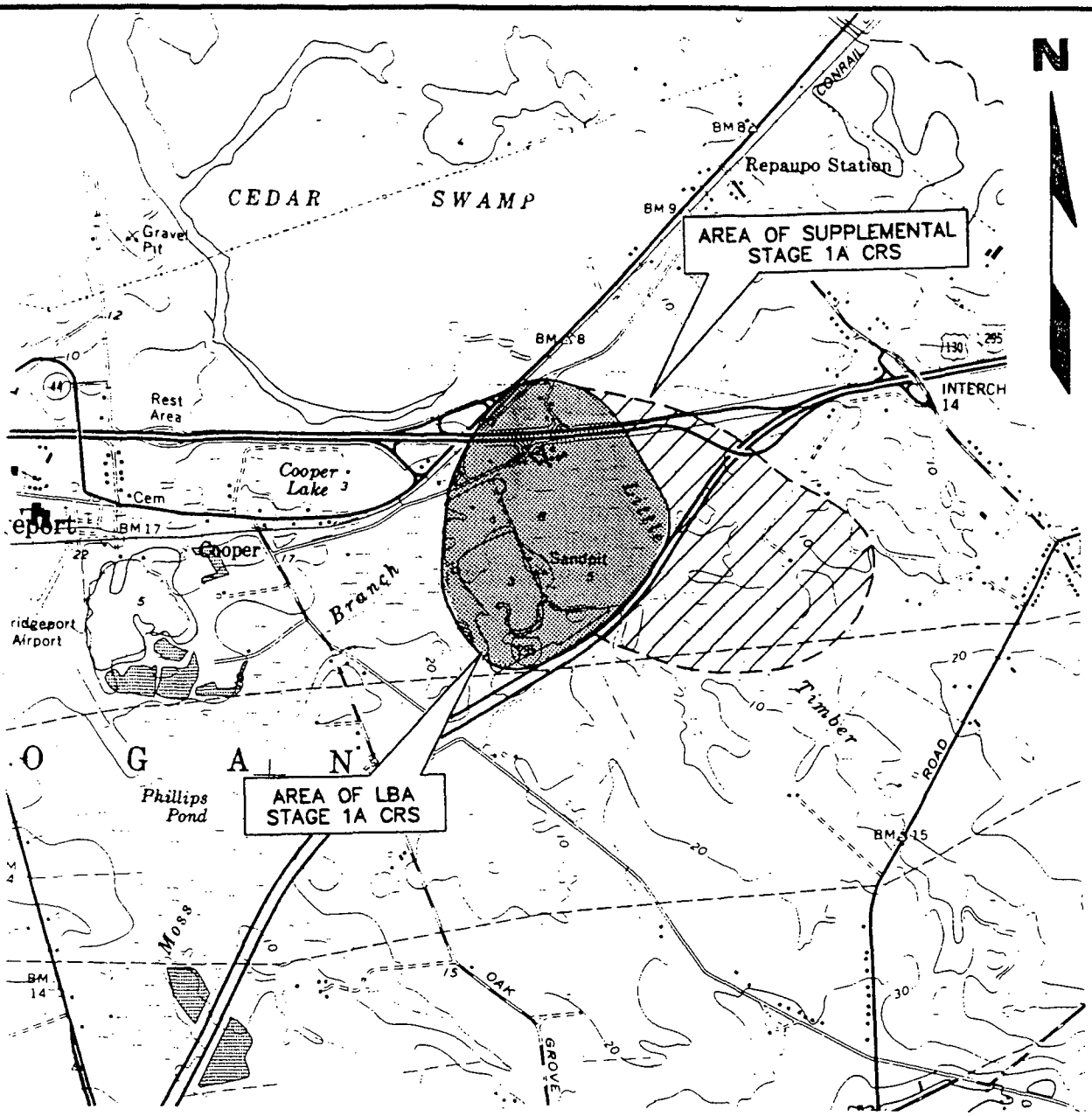
V. Restoration projects (public buildings; private homes)

The company has completed over 400 projects for a wide range of clients throughout the mid Atlantic and in New England. Completed historic projects include work on well-known historic sites such as the Old Barracks in Trenton, Ellis Island National Historic Site, Fort Mifflin on the Delaware, the Delaware and Raritan Canal, and, more locally, the Estellville Glassworks. Experience is more fully detailed in the enclosed statement of qualifications. Senior staff to be assigned to this project are Dr. Ian Burrow, company Vice President, and William Liebeknecht, Principal Investigator. Both fully meet the Secretary of the Interior's standards and qualifications.

E. Schedule

The following Schedule is proposed. The schedule is in calendar days after notice to proceed from the USEPA assuming access to the properties has been arranged.

Days	Activity
60	Completion of contracting and background research.
75	Completion of Stage IA survey.
90	Completion of Stage IB testing (currently defined areas).
120	Submission of draft Technical Memorandum to Roux Associates.
150	Submission of final Technical Memorandum to USEPA.



2,000' 0' 2,000'

Title:

AREAS OF LBA STAGE 1A AND PROPOSED SUPPLEMENTAL STAGE 1A CULTURAL RESOURCE SURVEYS

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

SOURCE:

U.S.G.S. BRIDGEPORT, N.J., QUADRANGLE 1967
7.5 MINUTE SERIES (TOPOGRAPHIC)
PHOTOREVISED 1986

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 10/23/97	Figure 1
	Prepared by: J.R.M.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301072	

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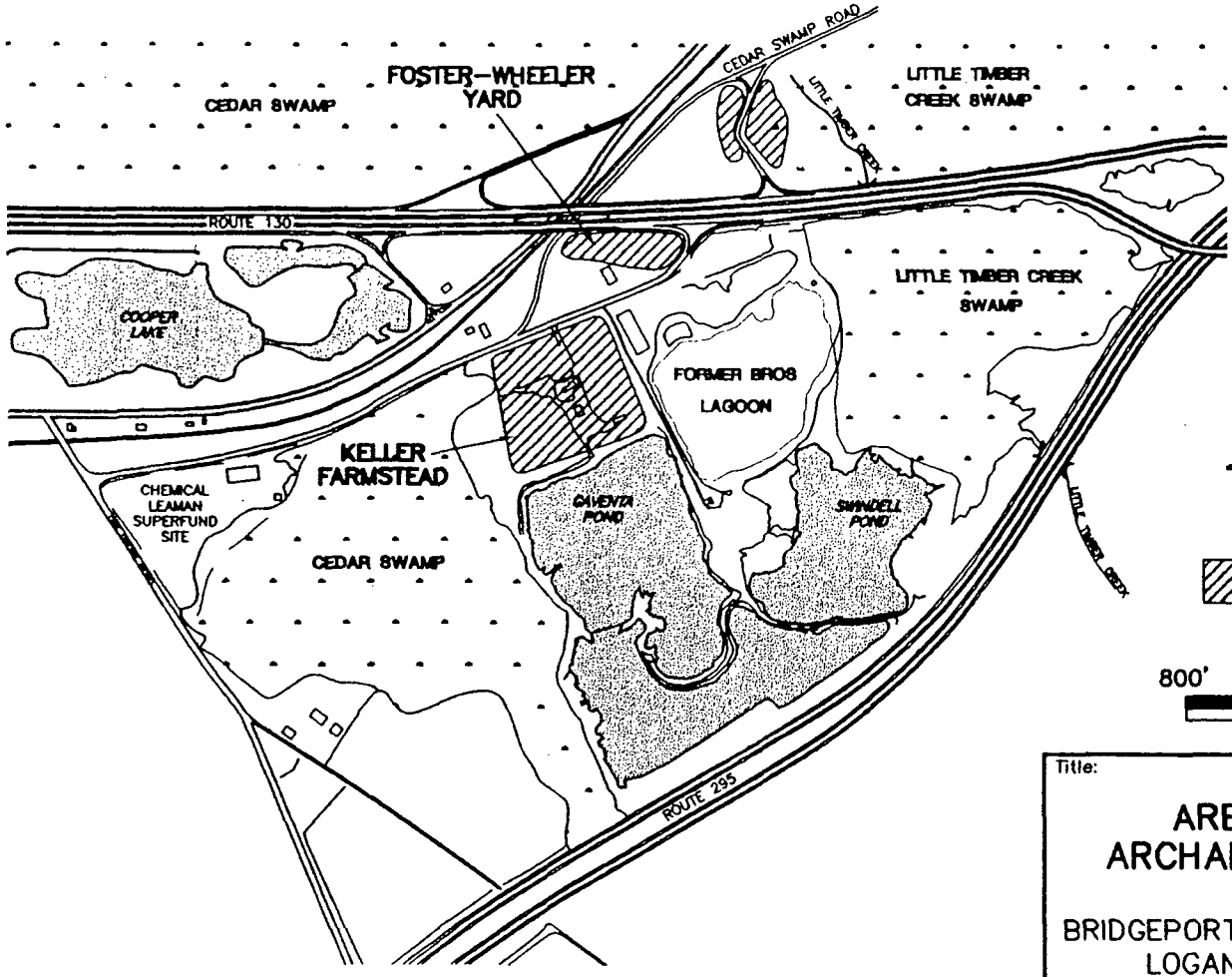

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EXPLANATION

WETLANDS

AREA OF SUSPECTED ARCHAEOLOGICAL SENSITIVITY IDENTIFIED BY LOUIS BERGER & ASSOCIATES

800' 0' 800'

Title:

AREAS OF SUSPECTED ARCHAEOLOGICAL SENSITIVITY

BRIDGEPORT RENTAL & OIL SERVICES SITE
LOGAN TOWNSHIP, NEW JERSEY

Prepared For:

BROS TECHNICAL COMMITTEE

ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: B.G.	Date: 11/11/97	Figure 2
	Prepared by: J.R.M.	Scale: SHOWN	
	Project Mgr: N.R.	Revision:	
	Proj No: 49301J05	File No: 49301071	

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Richard W. Hunter
PRESIDENT

Ian C. Burrow
VICE PRESIDENT

IAN C.G. BURROW
Vice President/Principal Archaeologist, Ph.D., SOPA

Education

Ph.D., History and Archaeology, University of Birmingham, England, 1979

B.A., History and Archaeology, University of Exeter, England, 1971

Experience

1988- Principal Archaeologist, Hunter Research, Inc., Cultural Resource Consultants, Trenton, NJ

Vice President and stockholder of firm providing archaeological and historical research, survey, excavation, evaluation, and report preparation services in the Northeastern United States. Specific expertise in historical and industrial archaeology (mills, iron and steel manufacture, pottery manufacture), historical geography, historic landscape analysis.

Participation in:

- Project management, budgeting and scheduling
- Proposal preparation and client negotiation
- Hiring and supervision of personnel
- Supervision of research, fieldwork, analysis and report preparation
- Development of computer and data management systems
- Development of public outreach initiatives

1986-1988 Director, Oxford Archaeological Unit, Oxford, England

Principal in charge of archaeological projects.
Responsibilities included:

- Overall management of organization
- Project design and cost analysis
- Survey, excavation, analysis and reports
- Public education, fund raising and public relations
- Implementation of computerized finance system
- Recruitment and supervision of personnel

1986-1988 Associate Staff Tutor, Department of External Studies, University of Oxford, England
Provided:

- Aid to Staff Tutor in Archaeology in planning organizing and teaching courses
- Administration of Oxford University Archaeology In-Service Training Program
- Design and teaching of courses for summer schools run jointly by the University of Oxford and U.S. universities and institutions
- Teaching within adult education program

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Hunter Research, Inc. Historical Resource Consultants 120 West State Street, Trenton, NJ 08608-1185 609/695-0122 609/695-0147 Fax
e-mail address: hri@hunterr.com http://hunterr.com/hunter.html

1979-1986 County Archaeologist, Somerset County Council, England

Responsibilities for public archaeology in a county of 1500 square miles containing c. 10,000 sites included:

- Development and implementation of historic preservation policies
- Survey, excavation, analysis and reports
- Project planning, budgeting and scheduling
- Recruitment and supervision of personnel
- Promotion of public interest in local archaeology and historic preservation

1975-1979 Archaeological Field Officer, Shropshire County Council, England

Designed and compiled comprehensive archaeological data base for use in historic preservation and planning.

1974-1986 Adult Education Tutor, Universities of Birmingham and Bristol, England

Designed, prepared and taught numerous courses on historic and prehistoric archaeology.

Special Skills and Interests

- 18th-century military sites
- archaeology and standing buildings
- urban archaeology
- archaeological database management

Selected Publications

"Thundercloud and Archaeologist: Indian Burials and the Study of the Past in New Jersey." In Search of Cult, Carver, Martin (ed). Boydell Press, 1993, 203-212.

"Contracting Archaeology? Cultural Resource Management in New Jersey, U.S.A." (with Richard Hunter). The Field Archaeologist (Journal of the Institute of Field Archaeologists) 12, March 1990, 194-200.

"Pretty Village to Urban Place: 18th Century Trenton and Its Archaeology" (with Richard Hunter) New Jersey History, Volume 114, Numbers 3-4, Fall/Winter 1996, 32-52

"Excavations at 5-8 Fore Street, Taunton 1979."Somerset Archaeological and Natural History 132 (1988), 95-164.

Oxford the Buried City. Co-editor, Oxford Archaeological Unit, 1987.

"Hillforts and the Iron Age." In The Archaeology of Avon, ed. M. Aston and R. Iles, Avon Council, 41-51, 1987.

"Conservation Archaeology and Planning" (with D. Baker). The Planner. February 1986.

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"We've Got Thousands of These Here Too!": Significance Assessment and Farm Archaeology in New Jersey." Paper presented at the Middle Atlantic Archaeology Conference, Ocean City, Maryland, March 1996

County Archaeological Records: Progress and Potential. Editor and contributor. Association of County Archaeological Officers. 1985.

"Hillfort and Hilltop Settlement, 1000 B.C.- 1000 A.D."In The Archaeology of Somerset: A New Review to A.D. 1500, ed. I.C.G. Burrow and M. Aston, Somerset County Council, 82-97, 1982.

"Hill-forts after the Iron Age: The Relevance of Surface Fieldwork." In Hill-fort Studies: Essays Presented to A.H.A. Hogg, ed. G. Guilbert, Leicester University Press, 122-149, 1981.

"Roman Material from Hillforts." In The End of Roman Britain, British Archaeological Reports, British Series 71, 212-229, 1979.

"Air Photography and Shropshire Archaeology." Aerial Archaeology 2: 64-68, 1978.

"The Town Defences of Exeter." Transactions of the Devonshire Association 109: 13-40, 1977.

Editor of and frequent contributor to the journal Somerset Archaeology and Natural History, 1979-1986; frequent contributor to the journal Popular Archaeology, 1980-1983.

Professional Affiliations

Society of Professional Archaeologists (Certification in Field Research and Archaeology Administration)
Professional Archaeologists for New York City (PANYC)
Society for Historical Archaeology, accredited 1991
Archaeological Society of New Jersey
Institute of Field Archaeologists, Founder Member (Member of Contract Archaeology Steering Committee, 1987-1988)
Association of County Archaeological Officers (Chairman 1984-1986)
Council for British Archaeology (Member of Executive Board, 1985-1988; Invited Member on Working Party on Public Attitudes to Archaeology, 1981-1983; Chairman for Southwest England Regional Group, 1980-1985)

Awards

Elected Fellow of the Society of Antiquaries of London
Colt Fund Award (from Society of Medieval Archaeology)
Maltwood Fund Award (from the Royal Society of Arts)

Richard W. Hunter
PRESIDENT

Ian C. Burrow
VICE PRESIDENT

WILLIAM B. LIEBEKNECHT
Principal Investigator, MA

Education

M.A., Public History, Rutgers University, Camden, New Jersey, 1993

B.A., Anthropology, Beloit College, Beloit, Wisconsin, 1984

Experience

1993- Principal Investigator, Hunter Research, Inc., Trenton, NJ

1991 Senior Archaeologist, Hunter Research, Inc., Trenton, NJ

Technical and managerial responsibilities for selected field and laboratory components of archaeological projects.
Participation in:

- Survey, excavation, analysis, and reports
- Project supervision and on-site management
- Management of laboratory operations and graphics production
- Supervision of laboratory and drafting personnel
- Preparation of proposals
- Recruitment and supervision of personnel

1988-1991 Laboratory and Drafting Supervisor
Hunter Research, Inc., Trenton, NJ

1988 Field Supervisor
University of Delaware Center for Archaeological Research, Newark, DE (June - August)

Technical and supervisory responsibilities for crew personnel on field projects in Delaware.

1985-1988 Laboratory and Field Supervisor
Research & Archaeological Management, Inc. (RAM)
Highland Park, NJ

Supervised analyses of artifact assemblages from various cultural resource projects in the Northeast.

1984-1985 Research and Field Assistant, Historic Sites Research, Princeton, NJ

Special Skills and Interests

- early New Jersey ceramic manufacturing
- British ceramics
- Lower Delaware Valley prehistory

Publications

"The Fort Elfsborg Spoon," Bulletin of the Archaeological Society of New Jersey, 1986, No. 40, 45-46.

"Further Evidence: Clam Shell Fracturing Patterns From A Site In Monmouth County, New Jersey," The Archaeology and Ethnohistory of the Lower Hudson Valley and Neighboring Regions: Essays in Honor of Louis Brennan, 1991, Occasional Publications in Northeastern Anthropology, No.11.

"British Registry Marks," Bulletin of the Archaeological Society of New Jersey, 1993, No.48, 69-70.

"A Token Find," Bulletin of the Archaeological Society of New Jersey, 1995, No.50.

Professional Affiliations

Middle Atlantic Archaeological Conference
Eastern States Archaeological Federation
Southeastern Archaeological Conference
Archaeological Society of New Jersey, Third Vice President 1989-91
Lower Delaware Chapter of ASNJ, Museum Curator/Chapter Representative
Archaeological Society of New York
Archaeological Society of Delaware
Archaeological Society of Virginia
Wisconsin State Archaeological Society
Society for Pennsylvania Archaeology
The Society for Historical Archaeology
Council of Northeast Historical Archaeology
Salem Historical Society
Pennsville Historical Society, Archaeological Chairman

Awards

Archaeological Society of New Jersey Award of Appreciation, 1990
Who's Who Among Young Executives in America, 1992

Certifications

OSHA 40-hour Inital Training, Spring 1994
Hazardous Materials Supervisory Training, September 1994
Sediment and Stormwater Management Certification, 1994

E

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APPENDIX E

Statistical Analysis of Preliminary Investigation Data
Evaluation of Lead as an Inorganic Indicator Constituent

Summary

As discussed in Section 6.3.1 of the Work Plan, lead was identified as a potential inorganic indicator constituent for delineating the boundaries of the *de manifestis*, intermediate, and *de minimis* zones. The objective of this analysis was to evaluate if the lead concentrations were statistically correlated with concentrations of other inorganic COPCs at the site, and evaluate if lead is an appropriate indicator for delineation purposes.

Data

The analytical data from sediment samples collected from Little Timber Creek Swamp (Malcolm Pirnie 1996 - *Preliminary Phase Two Remedial Investigation*) were used as a basis for the statistical analysis. As shown on Figure A, the samples were collected along three parallel transects extending east from the former BROS Lagoon. A summary of the detected inorganic constituent concentrations is provided on Table A.

Methods

Exploratory Analyses - Exploratory analyses consisted of examination of frequency histograms, normal probability plots, Shapiro-Wilkes test for normality, univariate statistics, and bivariate scatter plots. The exploratory analysis was conducted on the original data as well as log-transformed data. The frequency histograms and normal probability plots for lead indicated that the data distributions were not normal, but have a bi-modal distribution consisting of two clusters, concentrations less than 300 mg/kg and concentrations greater than 1000 mg/kg. Further evaluation of each of these clusters indicated that the data distributions were better defined as log-normal distributions rather than normal distribution. Exploratory analyses for the other analytes also indicated left skewed distributions for most of the analytes, which were better described by a log-normal distributions rather than normal distribution in most cases. Based on these observations and the consideration that environmental concentrations of inorganic constituents have often been observed to be log-normally distributed, further statistical analysis were performed on the log-transformed data.

Bivariate Plots and Linear Regression Analysis - Potential correlation between lead concentrations and other inorganic constituents were examined using bivariate scatter plots and linear regression analysis. Bivariate scatter plots are an essential complement to linear regression analyses because visual examination of such plots may reveal non-linear relationships or data clusters which may not be evident based on the results of a regression analysis alone. Non-linearities in the data patterns may result in regression output which suggest no significant correlations when in fact such correlations may exist (Kleinbaum, Kupper, Muller, 1988).

Linear regression analysis generates numeric indexes of potential association, two of which, the square of the correlation coefficient (r^2) and the standard error of the slope, are widely used to quantitatively evaluate the significance of possible correlation's. The quantity r^2 measures the proportionate reduction in the sum of squares of vertical deviations using the least squares line $Y=Mx + C$ as compared to the arithmetic mean of Y. Conceptually, therefore, r^2 represents the proportion of the total variability in Y which may be attributed to the variability in X (Kleinbaum,

Kupper, Muller 1988). For environmental data, r^2 values greater than 0.5 to 0.6 are widely accepted as being indicative of a significant correlation between variables. The standard error of the fitted slope may be used to test the hypothesis that the true slope of the line is statistically different from 0 (0 slope indicates no correlation). If the probability estimate (p value) that the true slope of the line is equal to 0 is < 0.05, it may be concluded that there is sufficient evidence for a statistically significant correlation .

As previously discussed, the frequency histograms for lead suggested a bi-modal distribution consisting of two data clusters (<300 mg/kg and > 1000 mg/kg). Based on this observation, the bivariate plots and regression analyses were conducted on two separate sets of data:

- total data, and
- samples for which lead concentration exceed 300 mg/kg.

For the total data set, the bivariate scatter plots of log Pb vs. each of the indicator analytes are shown on Figures 1 through 10 respectively, whereas the linear regression analyses are given on Tables 1-10. For the low concentration data set, the bivariate scatter plots of log Pb vs. each of the indicator analytes are shown on Figures 11 through 20 respectively, whereas the linear regression analyses are given on Tables 11-20. A summary of the r^2 and p values from the regression analyses is presented below.

	Full Data Set			Pb <300 mg/kg			
Analyte	**r^2**	**p**	**Fig./Table**	**r^2**	**p**	**Fig./ Table**	**Comment**
Antimony	0.1	0.14	1	0.52	0.002	11	A
Arsenic	0.004	0.77	2	0.29	0.04	12	A
Barium	0.79	0.0001	3	0.66	0.0002	13	B
Cadmium	0.73	0.0001	4	0.55	0.0016	14	B
Chromium	0.611	0.0001	5	0.1	0.22	15	C
Copper	0.52	0.0001	6	0.51	0.002	16	B
Cyanide	0.054	0.286	7	0.75	0.001	17	A
Nickel	0.31	0.0057	8	0.57	0.001	18	A
Silver	0.072	0.21	9	0.74	0.0001	19	A
Zinc	0.52	0.001	10	0.66	0.0002	20	A

A) A significant correlation was observed between lead and antimony, arsenic, cyanide, and zinc levels in the low lead concentration group, whereas no correlation's were observed in the high concentration group. The overall correlation for nickel and zinc are statistically significant.

B) Significant correlation's were observed between lead and barium, cadmium, and copper in the low concentration group, and the high concentration group respectively. As a result, the data indicate a significant overall correlation between lead levels and the levels of barium, cadmium, and copper.

C) A significant overall correlation was observed for chromium. However, the correlation in the low concentration group is not statistically significant.

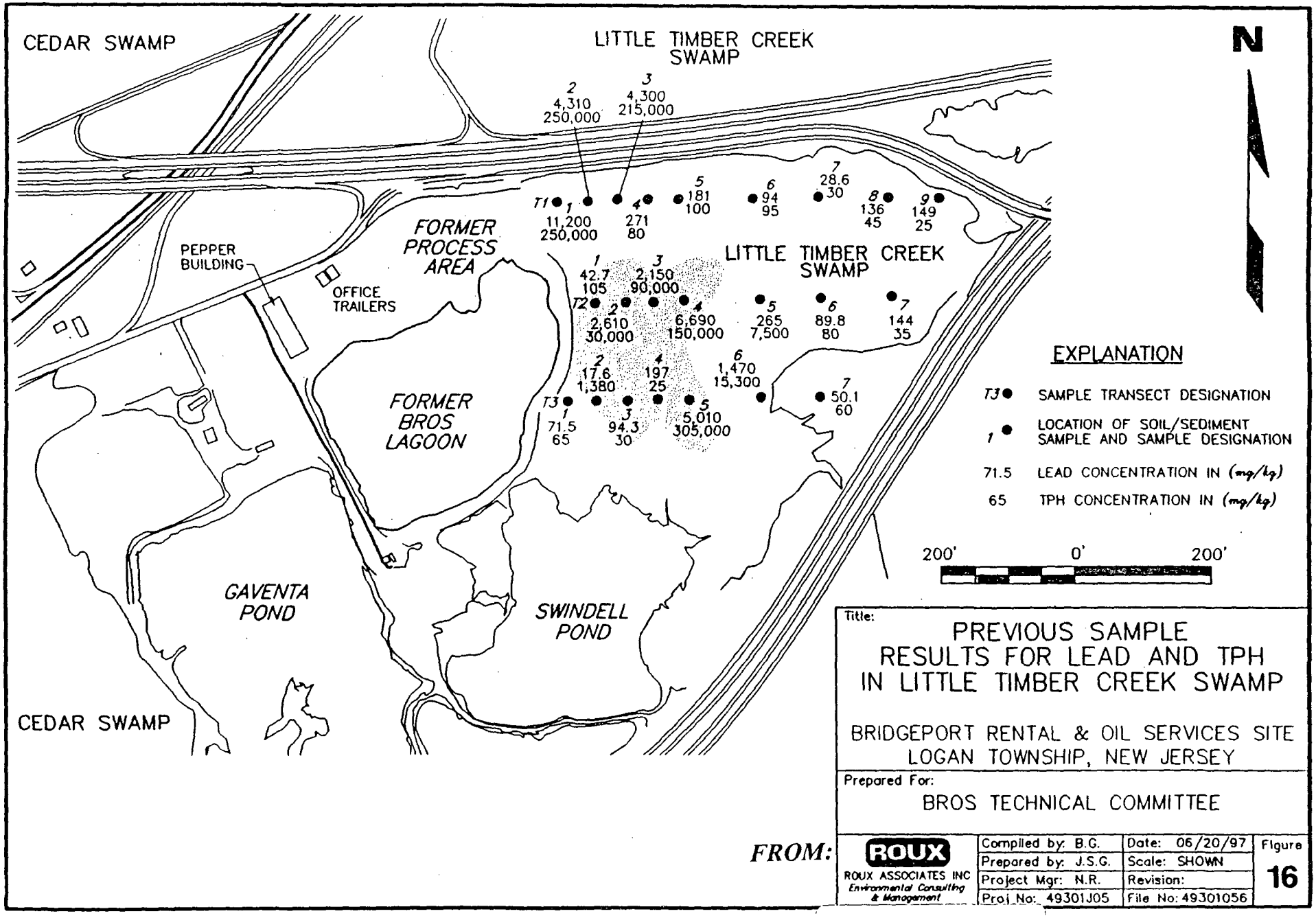
In summary, the concentrations of antimony, arsenic, cyanide, zinc, barium, cadmium, and copper are statistically significant when correlated with lead concentrations in sediment samples in where the lead concentrations are less than 300 mg/kg. In addition, the concentrations of barium, cadmium, copper, and chromium are significant when correlated with lead concentrations across the range of lead concentrations detected in the sediment samples.

References

Malcolm Pirnie, 1996, *Summary of the Phase Two remedial Investigation (RI) Work Performed to Date, Bridgeport Rental and Oil Services, Logan Township*

Kleinbaum, Kupper, Muller, 1988, *Applied Regression Analysis and Other Multivariable Methods*

Figure A



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BROS Phase 2 RI/FS Work Plan
Summary of Preliminary Investigation Data for Inorganics

Table A.

Sample ID	Transect	Lead		Antimony		Arsenic		Barium		Cadmium		Chromium		Copper		Cyanide		Nickel		Silver		Zinc	
		mg/kg	LOGPB	mg/kg	LOGSB	mg/kg	LOGAS	mg/kg	LOGBA	mg/kg	LOGCD	mg/kg	LOGCR	mg/kg	LOGCU	mg/kg	LOGCN	mg/kg	LOGNI	mg/kg	LOGAG	mg/kg	LOGZN
2	3	18	1.2	3.1	0.49	3.4	0.5	16	1.2	0.22	-0.66	27	1.4	8.6	0.9	5.4	0.7	3.7	0.6	1.1	0.04	18	1.2
7	1	29	1.5	4.3	0.63	11	1.1	106	2.0	0.31	-0.51	33	1.5	25	1.4	7.6	0.9	7.8	0.9	1.5	0.18	52	1.7
1	2	43	1.6	3.3	0.52	2.2	0.3	20	1.3	0.24	-0.62	16	1.2	15	1.2	5.6	0.7	2.8	0.4	1.2	0.08	30	1.5
7	3	50	1.7	12	1.08	6.3	0.8	17	1.2	0.77	-0.11	3.7	0.6	7	0.8	6.5	0.8	2.3	0.4	1	0.00	13	1.1
1	3	63	1.8	2.8	0.45	8.6	0.9	43	1.6	0.2	-0.70	38	1.6	25	1.4	5.4	0.7	11	1.0	1	0.00	97	2.0
6	2	90	2.0	7.4	0.87	12	1.1	243	2.4	0.53	-0.28	41	1.6	34	1.5	15	1.2	20	1.3	2.6	0.41	105	2.0
6	1	94	2.0	4.9	0.69	8	0.9	160	2.2	0.35	-0.46	31	1.5	22	1.3	8.7	0.9	11	1.0	1.8	0.26	69	1.8
3	3	94	2.0	4	0.60	4.8	0.7	36	1.6	0.29	-0.54	9.7	1.0	11	1.0	7.2	0.9	5	0.7	1.4	0.15	66	1.8
8	1	136	2.1	11	1.1	7.4	0.9	247	2.4	0.81	-0.09	26	1.4	38	1.6	22	1.3	20	1.3	4	0.60	99	2.0
7	2	144	2.2	12	1.1	4.1	0.6	309	2.5	0.86	-0.07	36	1.6	35	1.5	22	1.3	28	1.4	4.3	0.63	163	2.2
9	1	149	2.2	9.1	1.0	5.3	0.7	310	2.5	0.65	-0.19	23	1.4	40	1.6	17	1.2	17	1.2	3.3	0.52	110	2.0
5	1	181	2.3	17	1.2	17	1.2	287	2.5	1.2	0.08	28	1.4	45	1.7	29	1.5	25	1.4	6.2	0.79	159	2.2
4	3	197	2.3	59	1.8	11	1.0	230	2.4	3.8	0.58	117	2.1	30	1.5	33	1.5	10	1.0	5	0.70	167	2.2
5	2	265	2.4	12	1.1	15	1.2	304	2.5	0.82	-0.09	26	1.4	27	1.4	21	1.3	19	1.3	4.1	0.61	93	2.0
4	1	271	2.4	20	1.3	16	1.2	402	2.6	1.4	0.15	46	1.7	78	1.9	35	1.5	30	1.5	7.1	0.85	193	2.3
6	3	1,470	3.2	39	1.6	10	1.0	439	2.6	2.5	0.40	49	1.7	24	1.4	22	1.3	17	1.2	3.3	0.52	129	2.1
2	2	2,150	3.3	7.2	0.9	2.5	0.4	512	2.7	1	0.00	84	1.9	36	1.6	13	1.1	10	1.0	2.6	0.41	107	2.0
3	2	2,610	3.4	10	1.0	8.1	0.9	925	3.0	3.6	0.56	140	2.1	51	1.7	18	1.3	26	1.4	3.6	0.56	270	2.4
3	1	4,300	3.6	8.3	0.9	14	1.1	1,340	3.1	7	0.85	340	2.5	73	1.9	16	1.2	20	1.3	3	0.48	386	2.6
2	1	4,340	3.6	5.5	0.7	5.6	0.7	1,330	3.1	6.2	0.79	110	2.0	63	1.8	8.8	0.9	17	1.2	1.8	0.26	321	2.5
5	3	5,010	3.7	24	1.4	3.1	0.5	1,220	3.1	1.5	0.18	59	1.8	42	1.6	12	1.1	8.1	0.9	2	0.30	69	1.8
4	2	6,690	3.8	7.6	0.88	3.6	0.6	1,980	3.3	3.4	0.53	210	2.3	70	1.8	14	1.1	20	1.3	2.7	0.43	173	2.2
1	1	7,800	3.9	7.7	0.89	22	1.3	7,440	3.9	13	1.11	345	2.5	396	2.6	6.9	0.8	92	2.0	1.8	0.26	2,650	3.4

Data is from: "Summary of the Phase 2 Remedial Investigation Work Performed to Date for Bridgeport Rental and Oil Services - Logan Township, New Jersey". March 1996.
Contract No. 68-W9-0051. Work Assignment No. 014-2L07.

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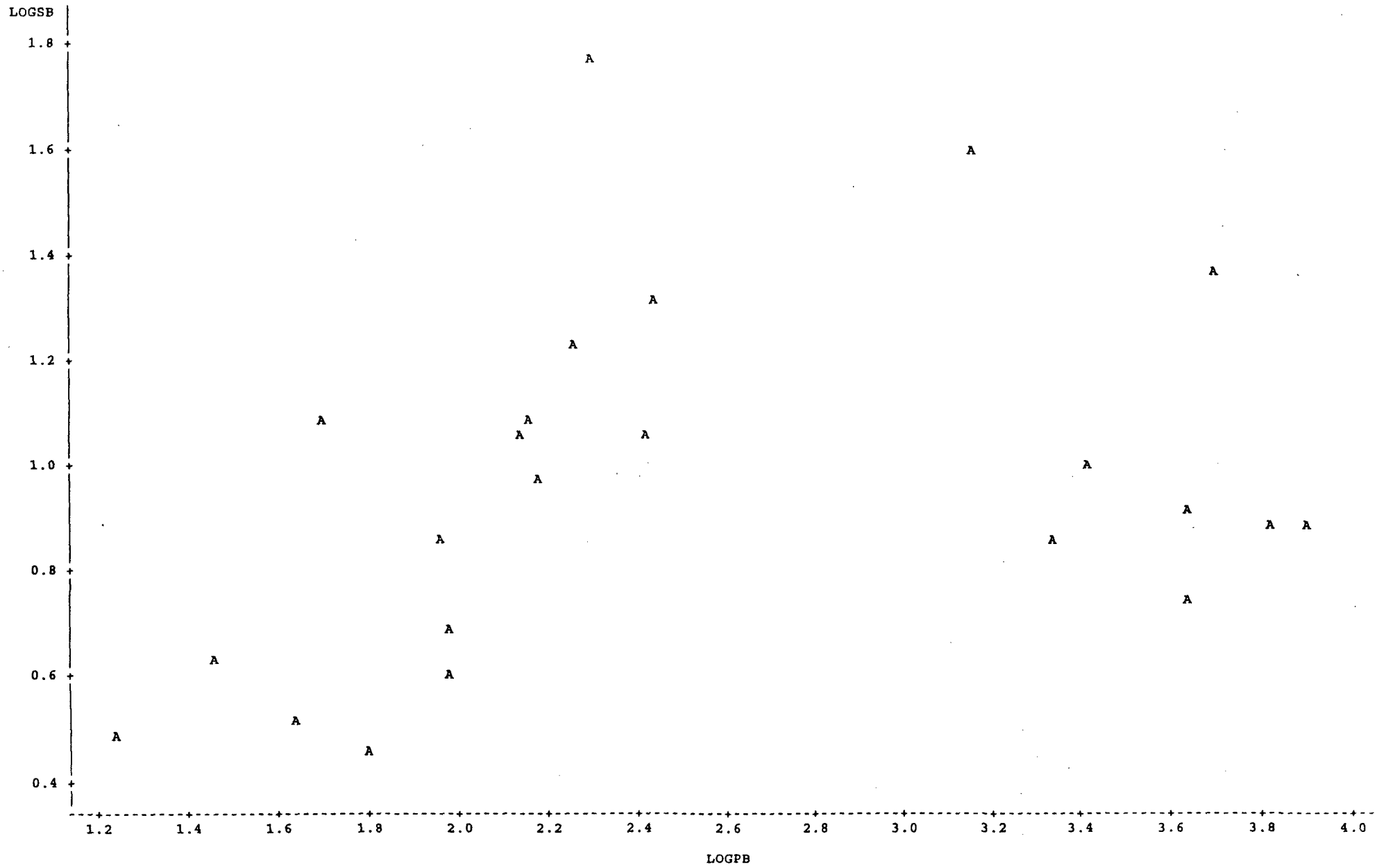
Plot of LOGSB*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



BROS Phase 'FS Work Plan
Statistical Analysis of iminary Investigation Data
Table 1 - ANOVA Table for Log Lead (mg/kg) vs Log Antimony (mg/kg)
Full Data Set

Model: MODEL1
Dependent Variable: LOGSB

Analysis of Variance

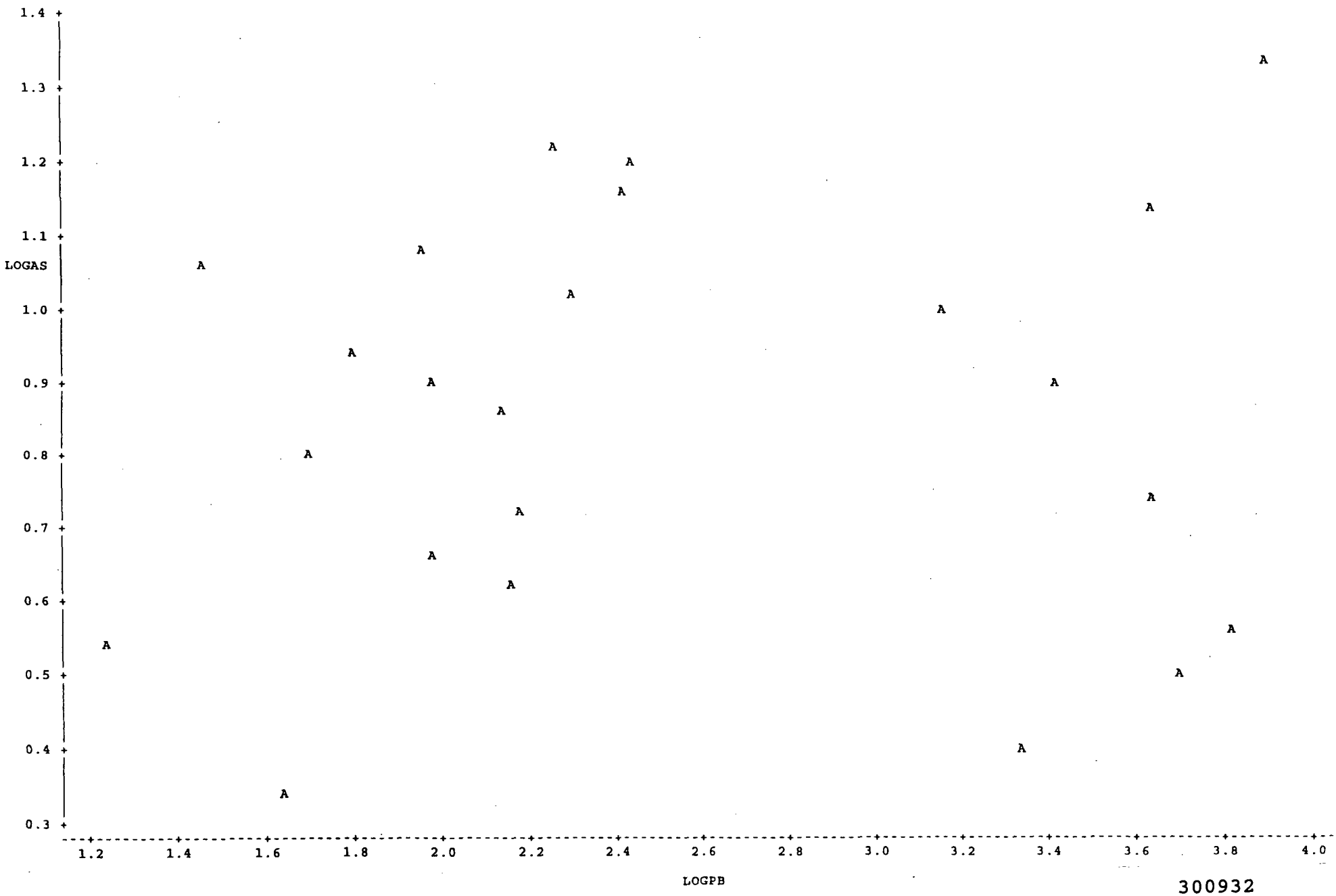
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.25507	0.25507	2.339	0.1411
Error	21	2.29001	0.10905		
C Total	22	2.54507			

Root MSE	0.33022	R-square	0.1002
Dep Mean	0.95923	Adj R-sq	0.0574
C.V.	34.42609		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.634938	0.22293742	2.848	0.0096
LOGPB	1	0.128126	0.08377571	1.529	0.1411

Plot of LOGAS*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



BROS Phase 'FS Work Plan
Statistical Analysis of iminary Investigation Data
Table 2 - ANOVA Table for Log Lead (mg/kg) vs Log Aresenic (mg/kg)
Full Data Set

Model: MODEL1
Dependent Variable: LOGAS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.00720	0.00720	0.086	0.7717
Error	21	1.74946	0.08331		
C Total	22	1.75666			

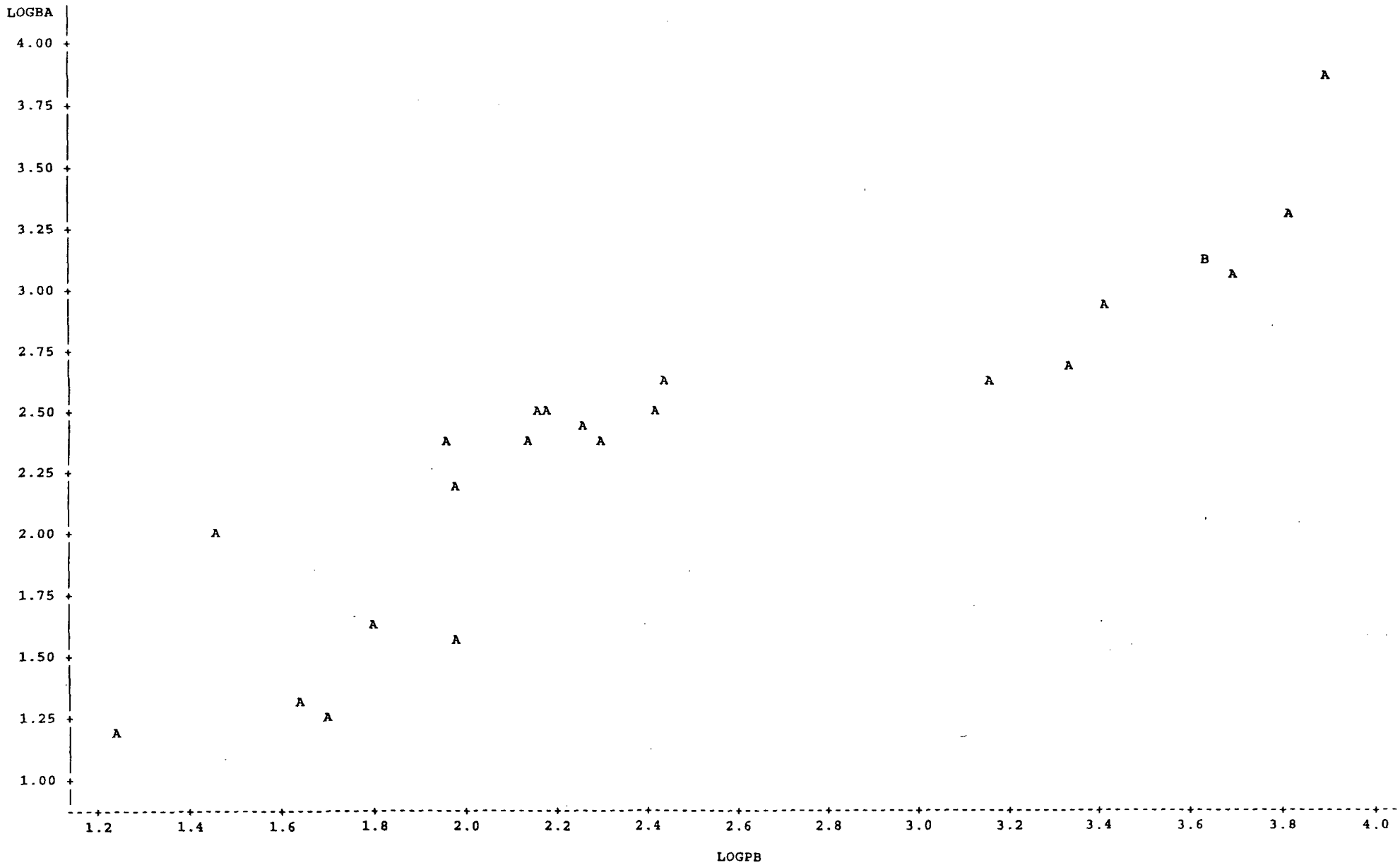
Root MSE	0.28863	R-square	0.0041
Dep Mean	0.85767	Adj R-sq	-0.0433
C.V.	33.65282		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.803186	0.19485741	4.122	0.0005
LOGPB	1	0.021527	0.07322376	0.294	0.7717

BROS Phas FS Work Plan
Statistical Analysis of iminary Investigation Data
Figure 3 - Plot of Log Lead (mg/kg) vs Log Barium (mg/kg)
Full Data Set

Plot of LOGBA*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



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BROS Phase [illegible] FS Work Plan
Statistical Analysis of Preliminary Investigation Data
Table 3 - ANOVA Table for Log Lead (mg/kg) vs Log Barium (mg/kg)
Full Data Set

Model: MODEL1
Dependent Variable: LOGBA

Analysis of Variance

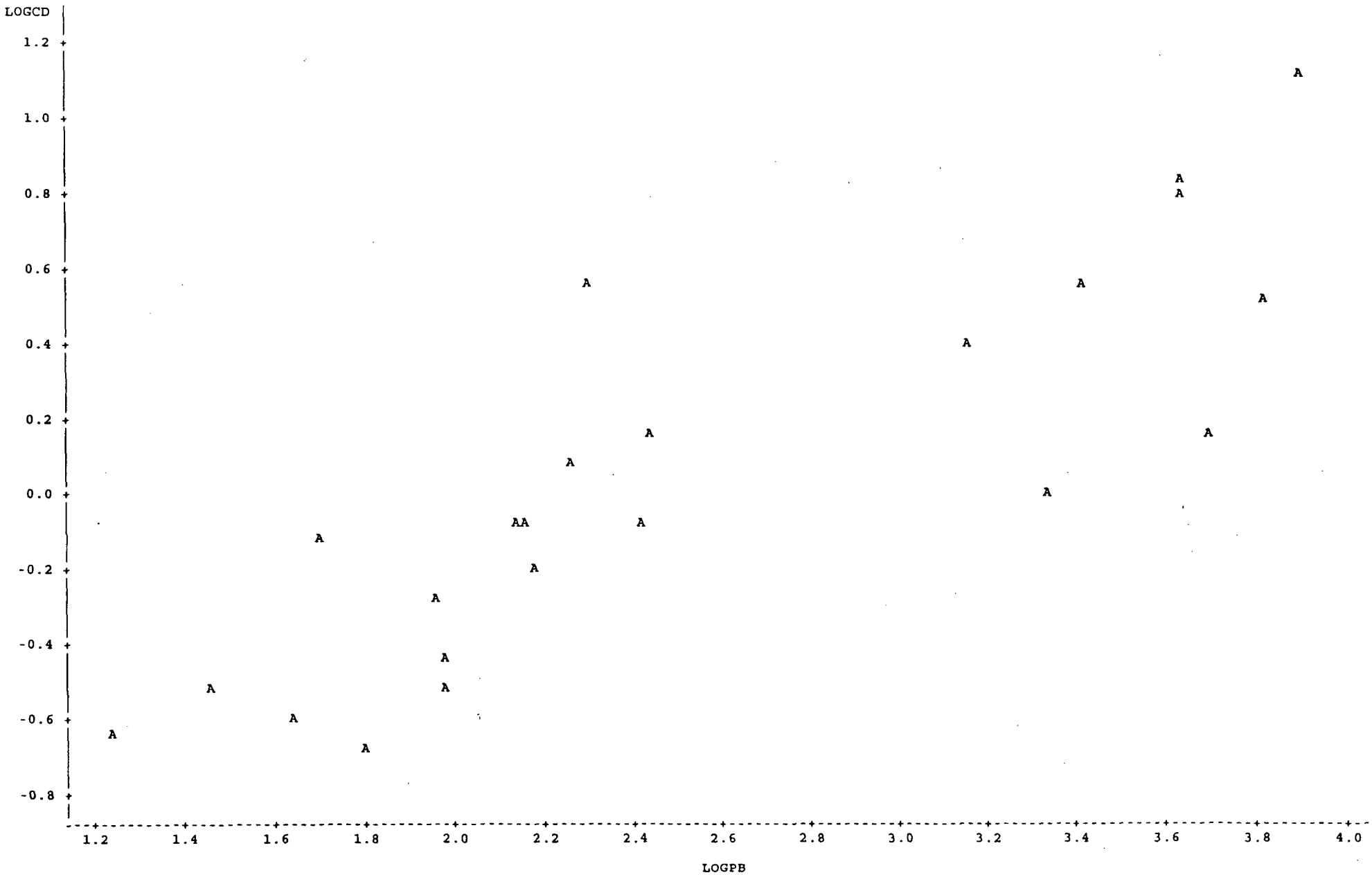
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	8.39367	8.39367	82.944	0.0001
Error	21	2.12513	0.10120		
C Total	22	10.51881			

Root MSE	0.31811	R-square	0.7980
Dep Mean	2.41923	Adj R-sq	0.7883
C.V.	13.14942		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.558944	0.21476217	2.603	0.0166
LOGPB	1	0.734997	0.08070360	9.107	0.0001

Plot of LOGCD*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



Model: MODEL1
Dependent Variable: LOGCD

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	4.31744	4.31744	57.702	0.0001
Error	21	1.57128	0.07482		
C Total	22	5.88872			

Root MSE	0.27354	R-square	0.7332
Dep Mean	0.03987	Adj R-sq	0.7205
C.V.	686.11519		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-1.294320	0.18466768	-7.009	0.0001
LOGPB	1	0.527136	0.06939465	7.596	0.0001

Figure 5 - Plot of Log Lead (mg/kg) vs Log Chromium (mg/kg)
Full Data Set

Plot of LOGCR*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.

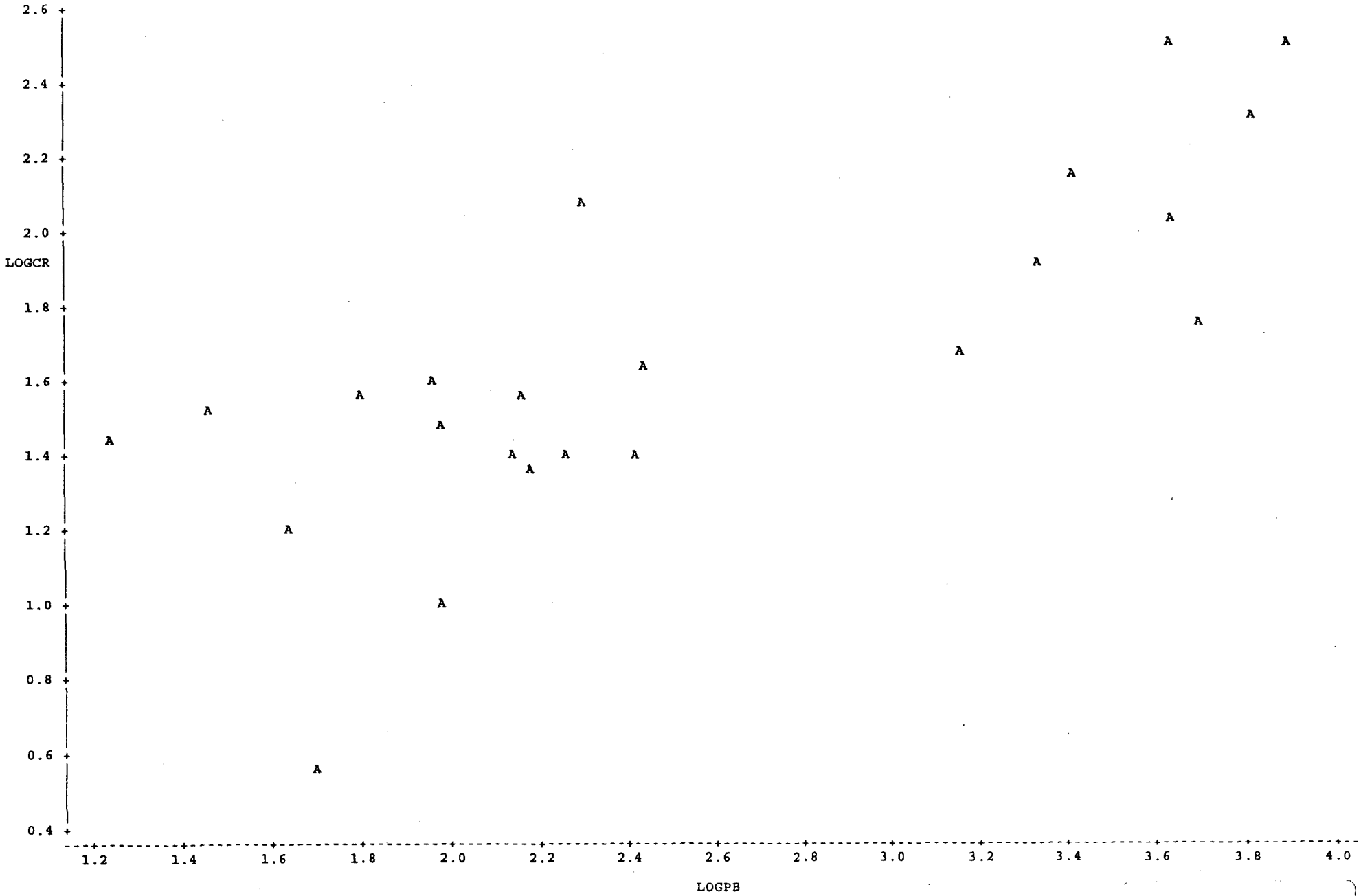


Table 5 - ANOVA Table for Log Lead (mg/kg) vs Log Chromium (mg/kg)
Full Data Set

Model: MODEL1
Dependent Variable: LOGCR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	2.96618	2.96618	33.106	0.0001
Error	21	1.88152	0.08960		
C Total	22	4.84770			

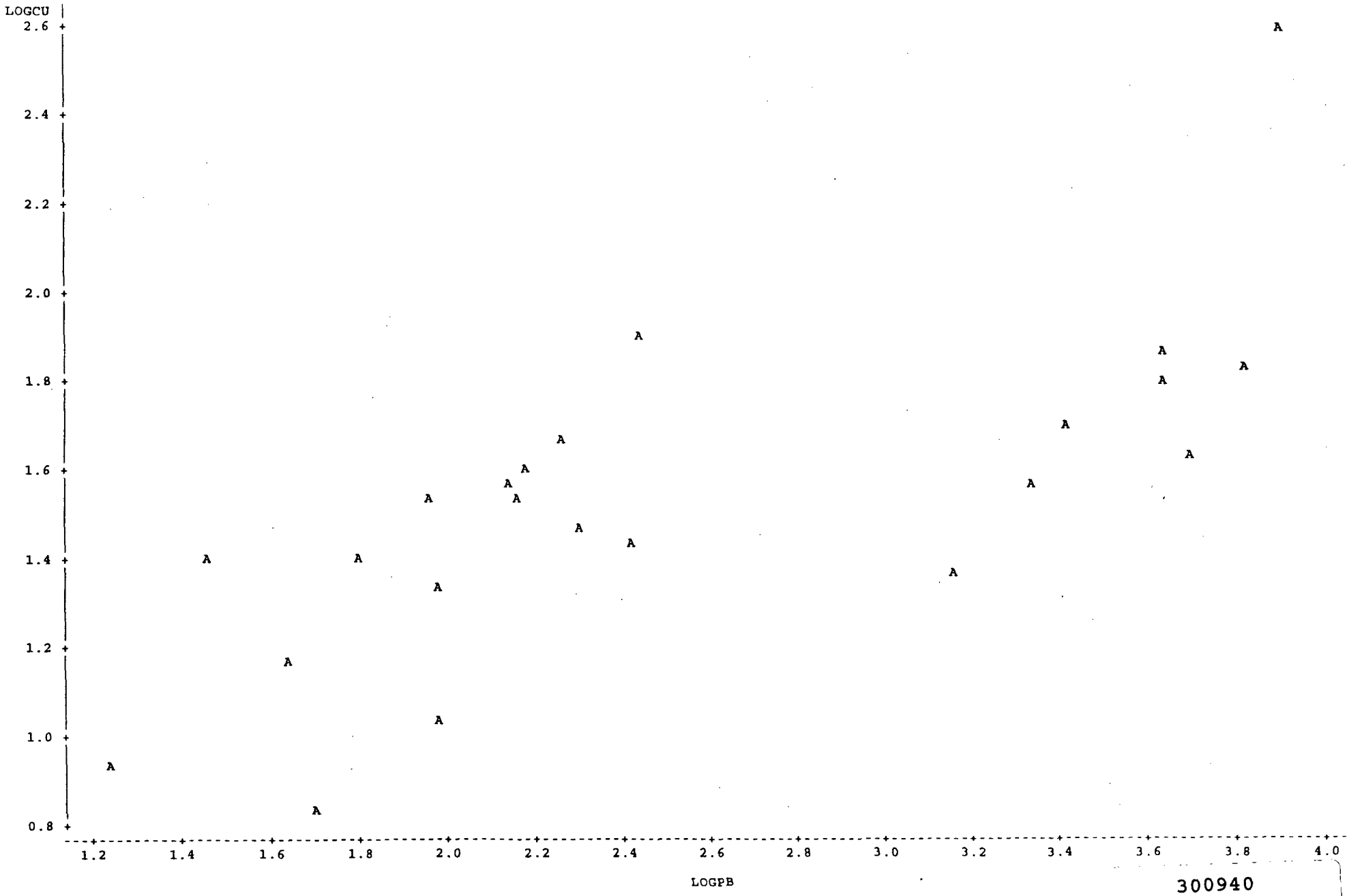
Root MSE	0.29933	R-square	0.6119
Dep Mean	1.66251	Adj R-sq	0.5934
C.V.	18.00447		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.556644	0.20207802	2.755	0.0119
LOGPB	1	0.436926	0.07593713	5.754	0.0001

BROS Phase FS Work Plan
Statistical Analysis of iminary Investigation Data
Figure 6 - Plot of Log Lead (mg/kg) vs Log Copper (mg/kg)
Full Data Set

Plot of LOGCU*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



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BROS Phase [illegible] FS Work Plan
Statistical Analysis of [illegible]liminary Investigation Data
Table 6 - ANOVA Table for Log Lead (mg/kg) vs Log Copper (mg/kg)
Full Data Set

Model: MODEL1
Dependent Variable: LOGCU

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.52455	1.52455	23.174	0.0001
Error	21	1.38151	0.06579		
C Total	22	2.90606			

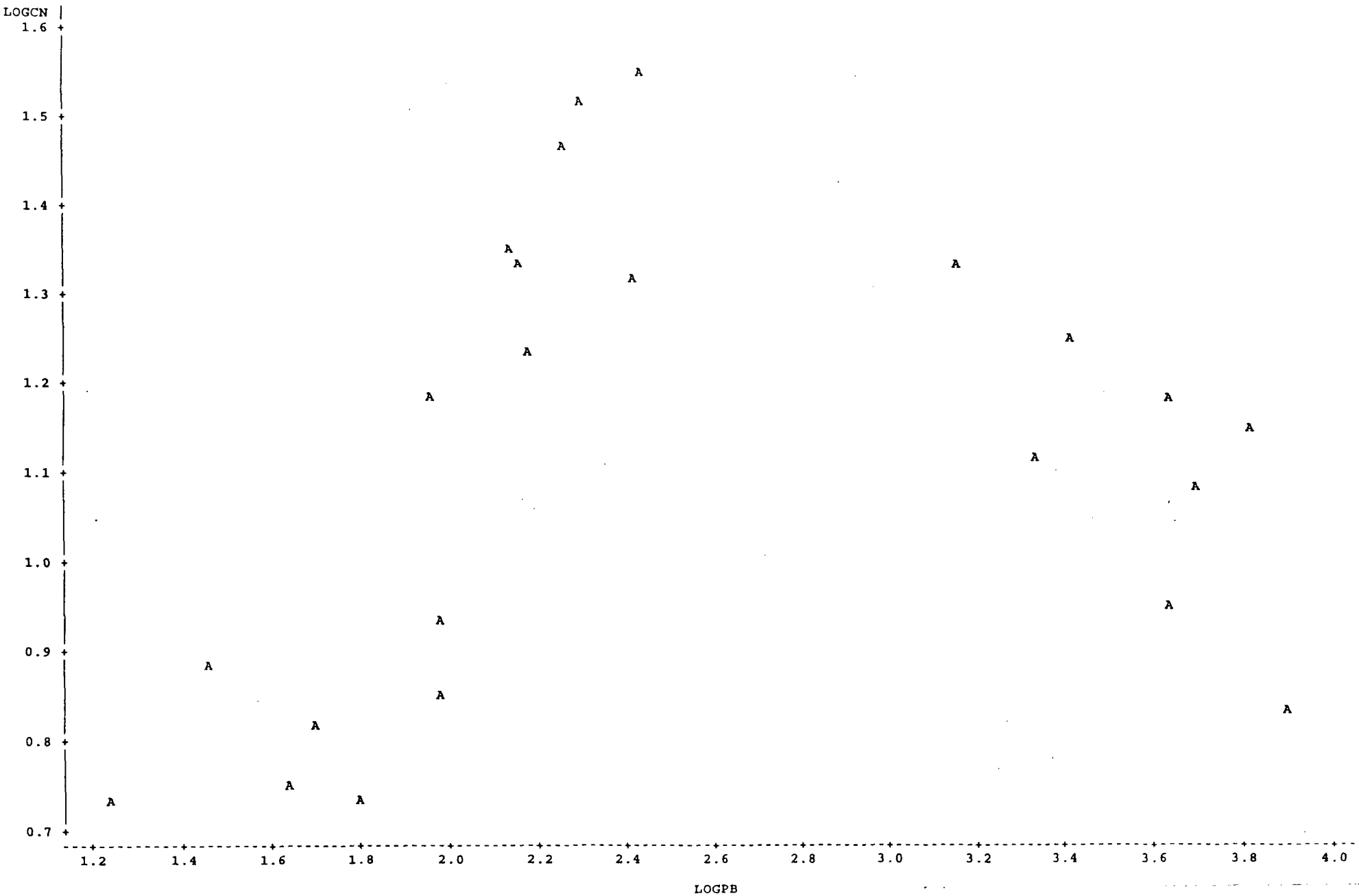
Root MSE	0.25649	R-square	0.5246
Dep Mean	1.53093	Adj R-sq	0.5020
C.V.	16.75374		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.738114	0.17315787	4.263	0.0003
LOGPB	1	0.313242	0.06506948	4.814	0.0001

BROS Phase[illegible] FS Work Plan
Statistical Analysis of [illegible]liminary Investigation Data
Figure 7 - Plot of Log Lead (mg/kg) vs Log Cyanide (mg/kg)
Full Data Set

Plot of LOGCN*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



Model: MODEL1
Dependent Variable: LOGCN

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.08085	0.08085	1.198	0.2860
Error	21	1.41688	0.06747		
C Total	22	1.49774			

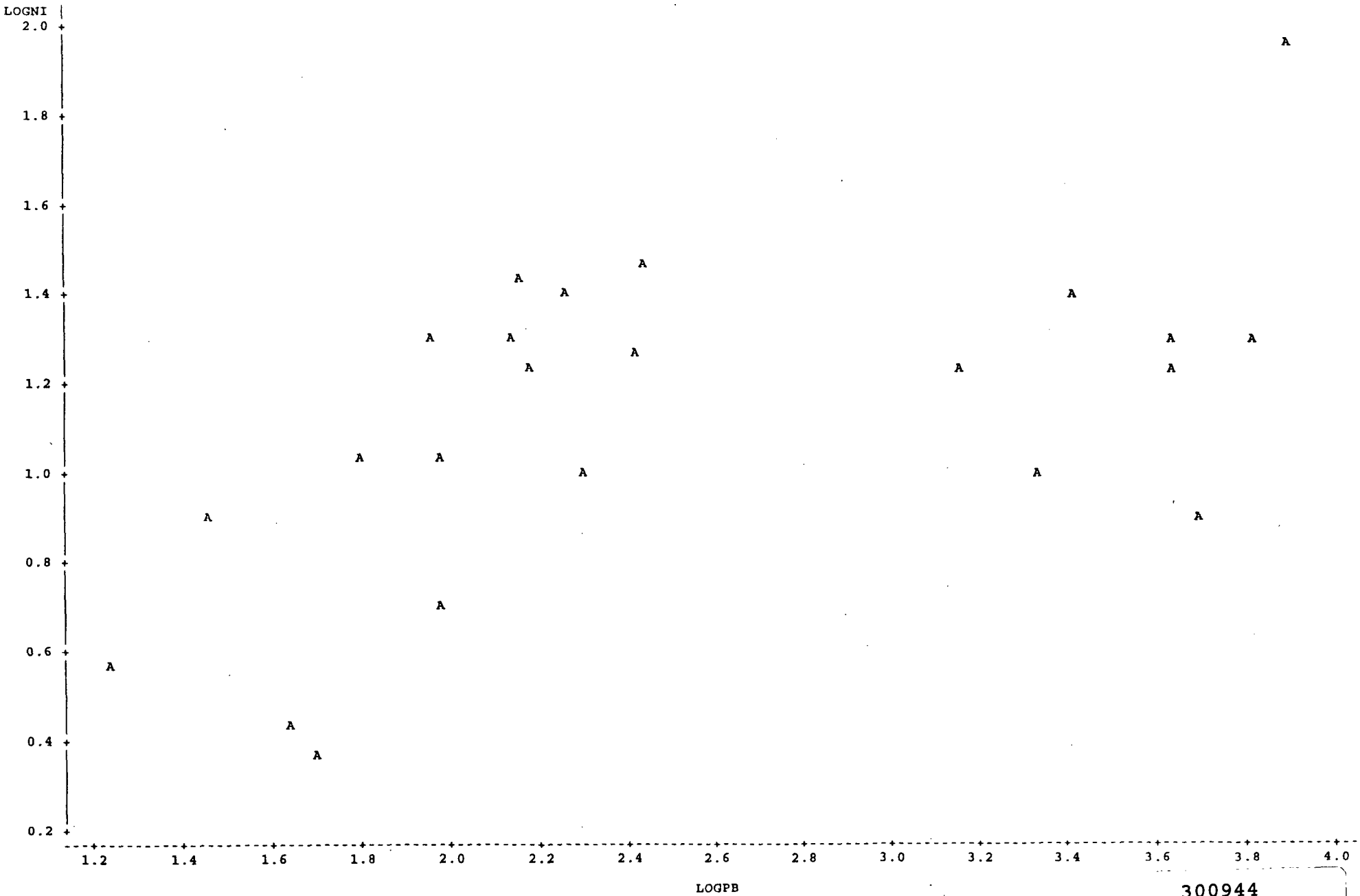
Root MSE	0.25975	R-square	0.0540
Dep Mean	1.11240	Adj R-sq	0.0089
C.V.	23.35059		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.929815	0.17536032	5.302	0.0001
LOGPB	1	0.072138	0.06589713	1.095	0.2860

Figure 8 - Plot of Log Lead (mg/kg) vs Log Nickel (mg/kg)
Full Data Set

Plot of LOGNI*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



Model: MODEL1
Dependent Variable: LOGNI

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.91885	0.91885	9.498	0.0057
Error	21	2.03159	0.09674		
C Total	22	2.95045			

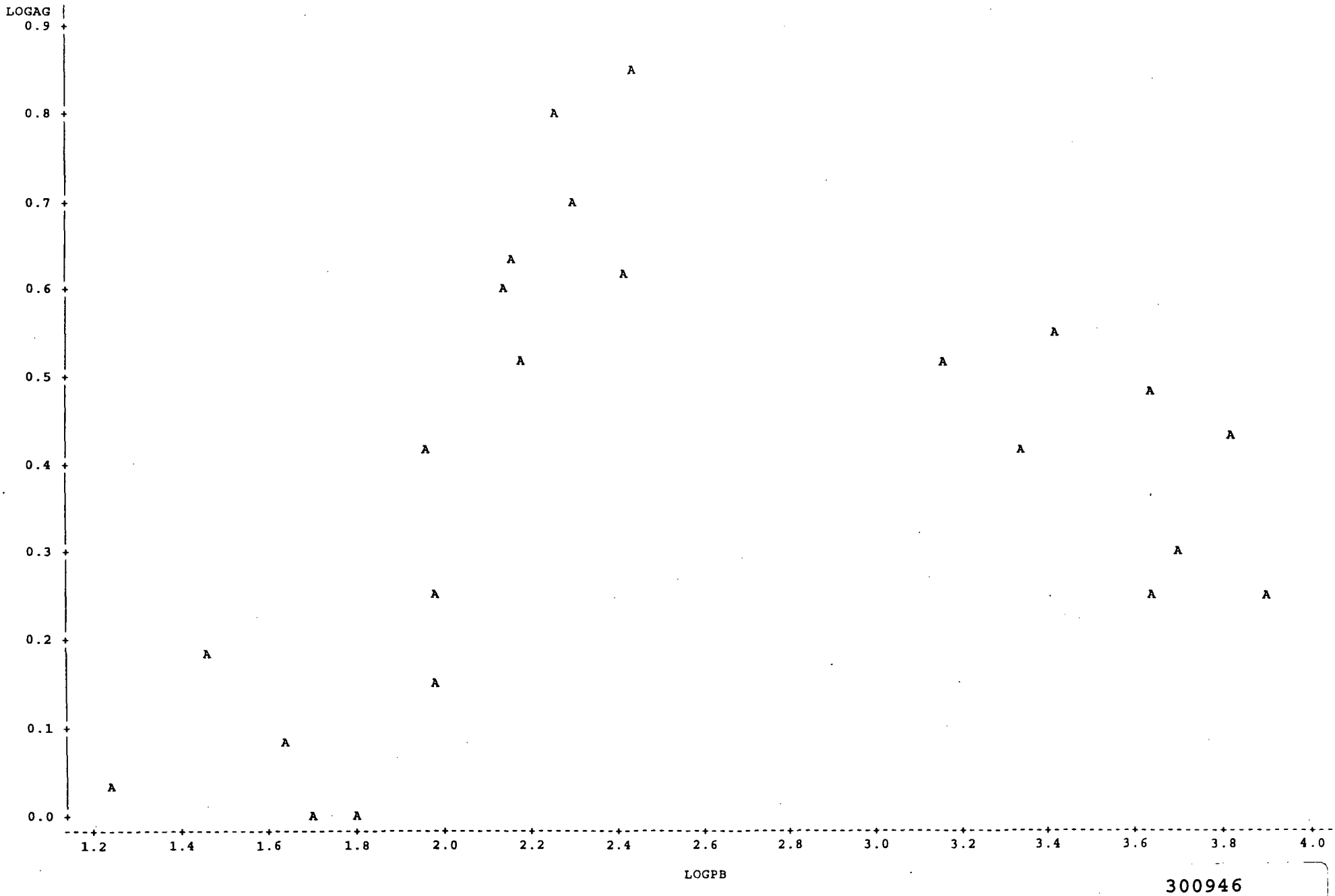
Root MSE	0.31103	R-square	0.3114
Dep Mean	1.12339	Adj R-sq	0.2786
C.V.	27.68725		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.507887	0.20998237	2.419	0.0247
LOGPB	1	0.243183	0.07890744	3.082	0.0057

BROS Phase FS Work Plan
Statistical Analysis of iminary Investigation Data
Figure 9 - Plot of Log Lead (mg/kg) vs Log Silver (mg/kg)
Full Data Set

Plot of LOGAG*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



Model: MODEL1
Dependent Variable: LOGAG

Analysis of Variance

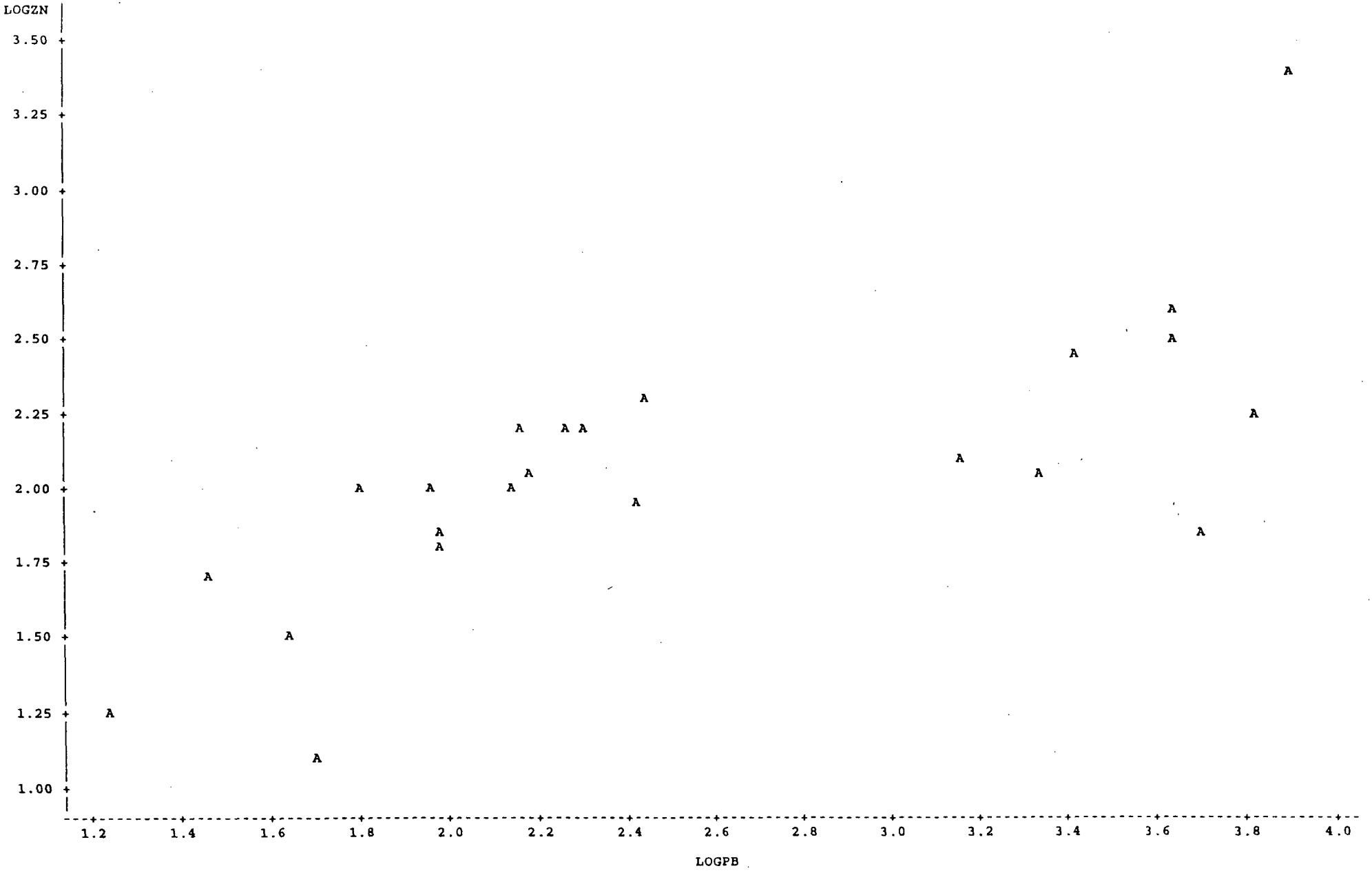
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.10084	0.10084	1.649	0.2131
Error	21	1.28418	0.06115		
C Total	22	1.38502			

Root MSE	0.24729	R-square	0.0728
Dep Mean	0.39271	Adj R-sq	0.0287
C.V.	62.96966		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.188807	0.16694667	1.131	0.2708
LOGPB	1	0.080562	0.06273543	1.284	0.2131

Plot of LOGZN*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



BROS Phase FS Work Plan
Statistical Analysis of iminary Investigation Data
Table 10 - ANOVA Table for Log Lead (mg/kg) vs Log Zinc (mg/kg)
Full Data Set

Model: MODEL1
Dependent Variable: LOGZN

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	2.46445	2.46445	22.004	0.0001
Error	21	2.35202	0.11200		
C Total	22	4.81647			

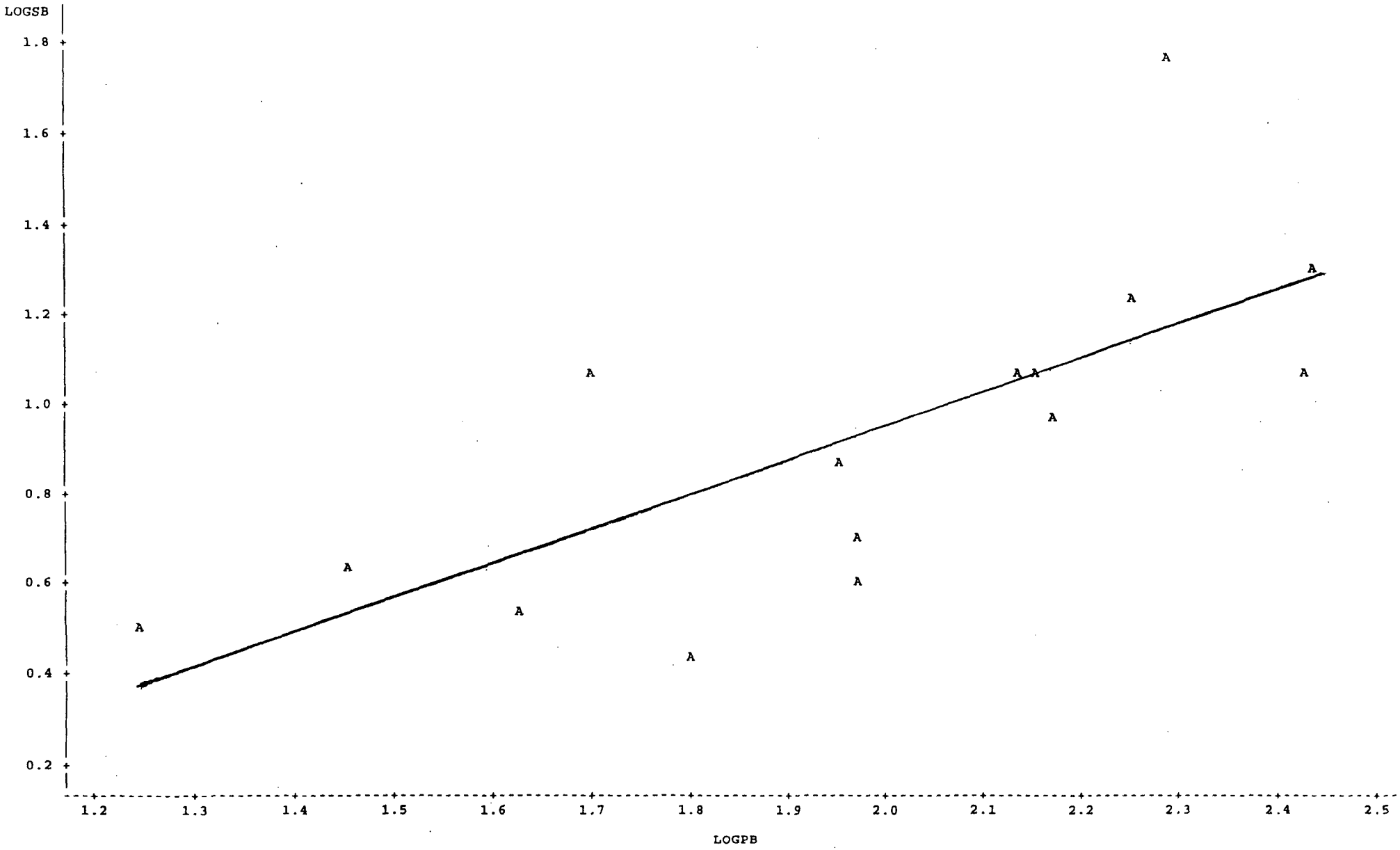
Root MSE	0.33467	R-square	0.5117
Dep Mean	2.05699	Adj R-sq	0.4884
C.V.	16.26970		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.048978	0.22593586	4.643	0.0001
LOGPB	1	0.398263	0.08490246	4.691	0.0001

Statistical Analysis of Preliminary Investigation Data
Figure 11 - Plot of Log Lead (mg/kg) vs Log Antimony (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGSB*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



OTE: 2 obs hidden.

Statistical Analysis of Preliminary Investigation Data
Table 11 - ANOVA Table for Log Lead (mg/kg) vs Log Antimony (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGSB

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.97886	0.97886	14.289	0.0023
Error	13	0.89053	0.06850		
C Total	14	1.86939			

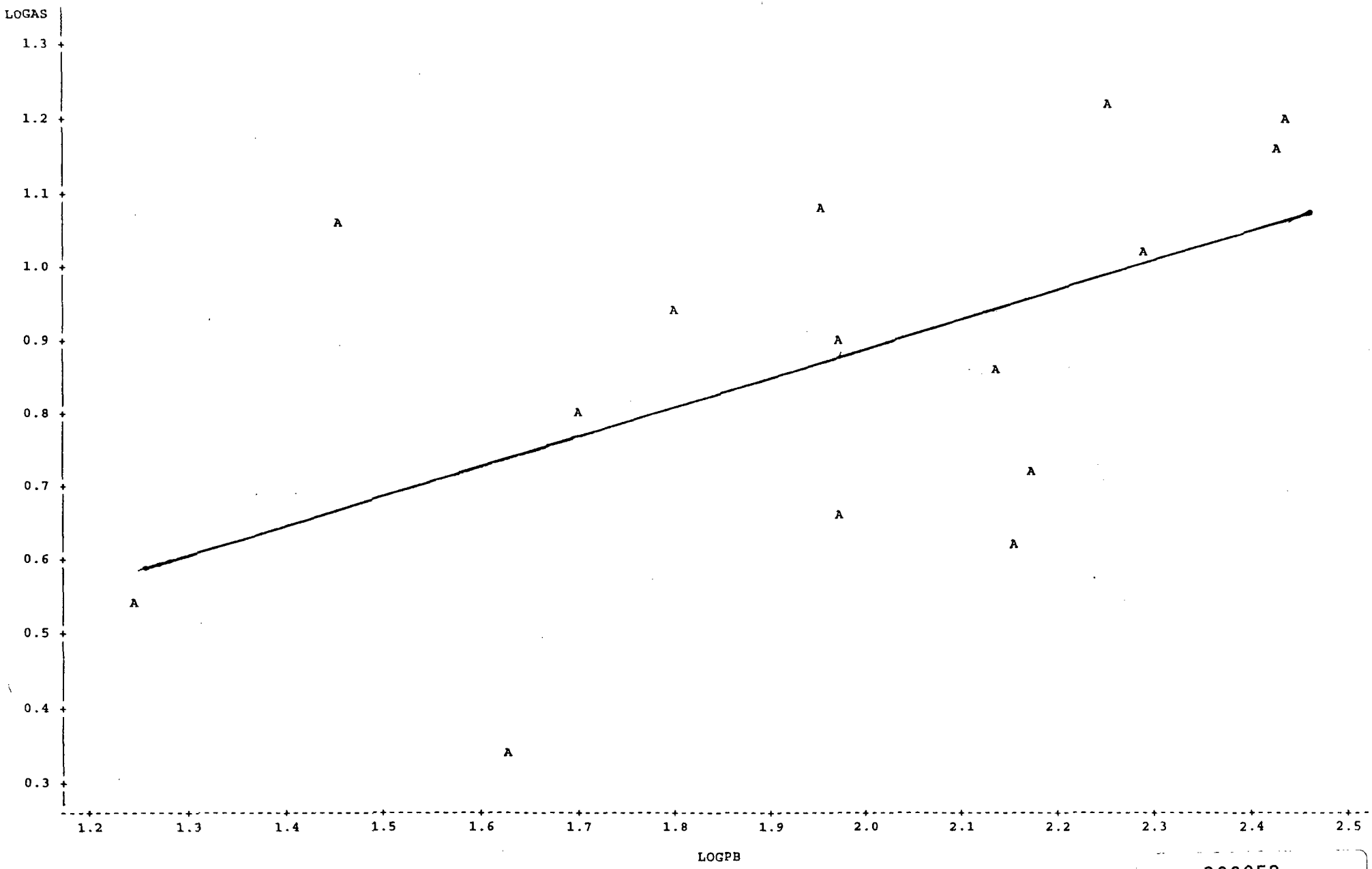
Root MSE	0.26173	R-square	0.5236
Dep Mean	0.92002	Adj R-sq	0.4870
C.V.	28.44828		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.570549	0.40006667	-1.426	0.1774
LOGPB	1	0.755137	0.19976517	3.780	0.0023

Figure 12 - Plot of Log Lead (mg/kg) vs Log Arsenic (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGAS*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 1 obs hidden.

300952

Statistical Analysis of Preliminary Investigation Data
Table 12 - ANOVA Table for Log Lead (mg/kg) vs Log Arsenic (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGAS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.28410	0.28410	5.408	0.0369
Error	13	0.68290	0.05253		
C Total	14	0.96701			

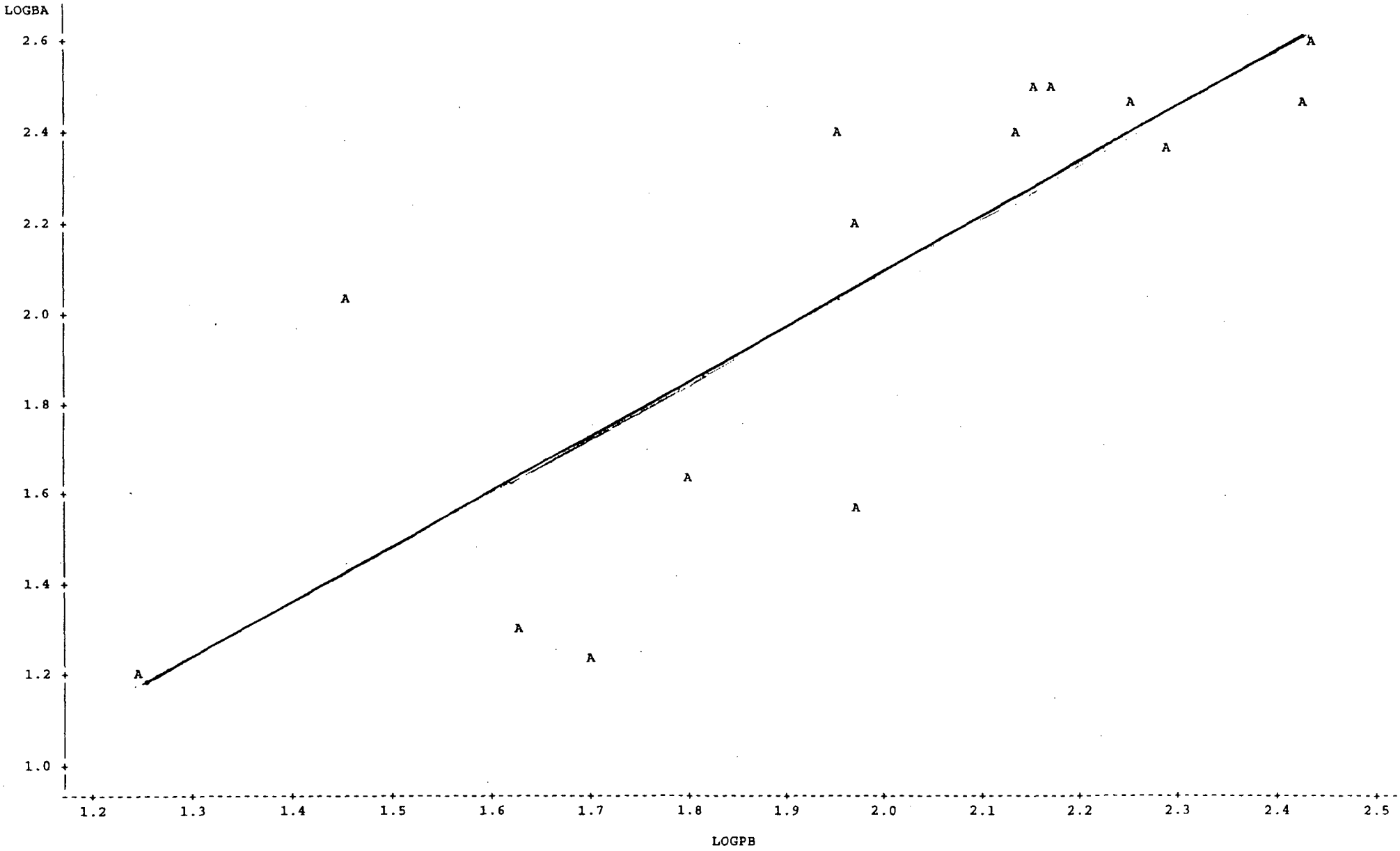
Root MSE	0.22920	R-square	0.2938
Dep Mean	0.87650	Adj R-sq	0.2395
C.V.	26.14908		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.073472	0.35033776	0.210	0.8371
LOGPB	1	0.406822	0.17493405	2.326	0.0369

Figure 13 - Plot of Log Lead (mg/kg) vs Log Barium (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGBA*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 2 obs hidden.

300954

Table 13 - ANOVA Table for Log Lead (mg/kg) vs Log Barium (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGBA

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	2.47617	2.47617	24.890	0.0002
Error	13	1.29331	0.09949		
C Total	14	3.76947			

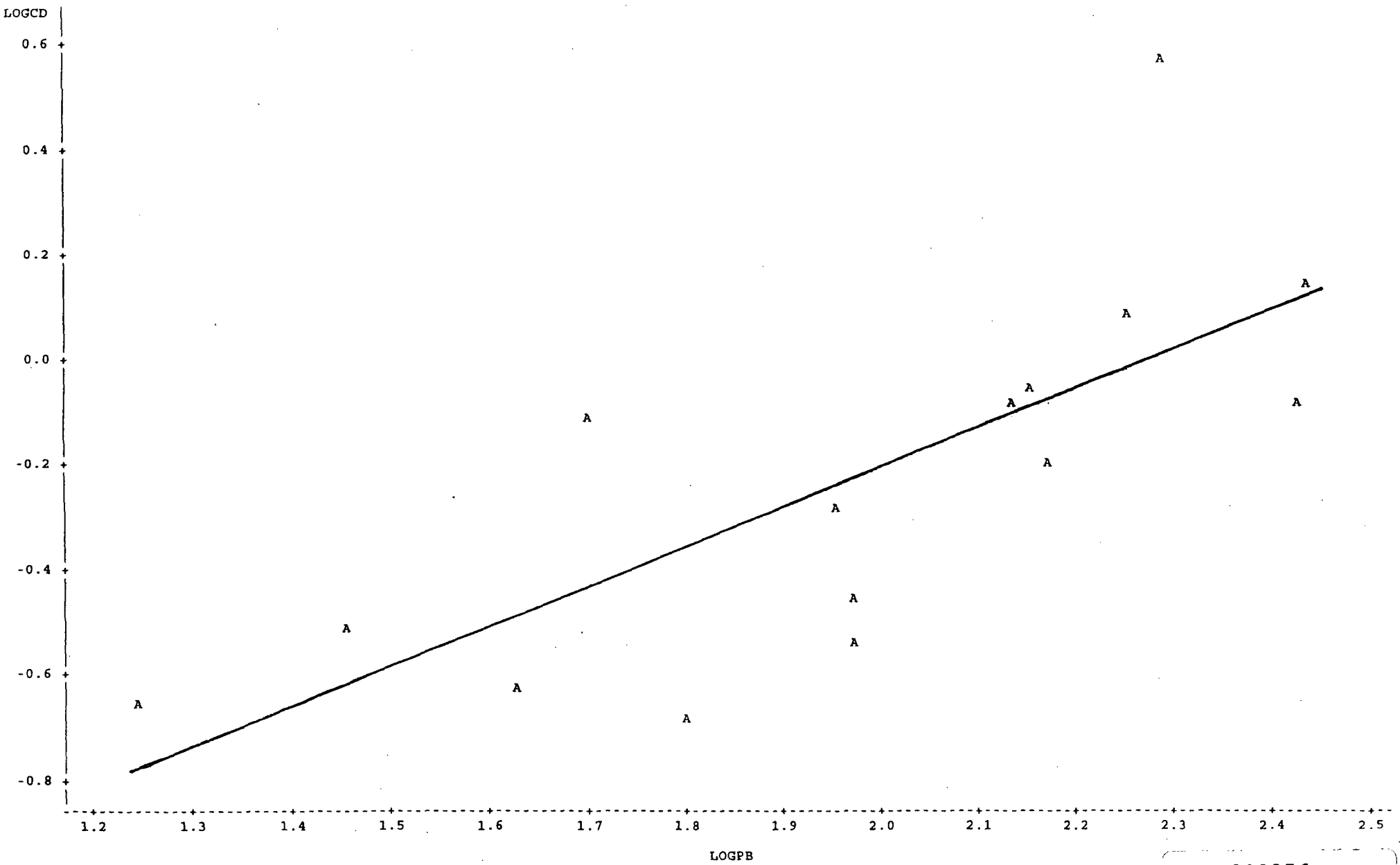
Root MSE	0.31541	R-square	0.6569
Dep Mean	2.05459	Adj R-sq	0.6305
C.V.	15.35160		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.316145	0.48212290	-0.656	0.5234
LOGPB	1	1.201037	0.24073829	4.989	0.0002

Figure 14 - Plot of Log Lead (mg/kg) vs Log Cadmium (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGCD*LOGPB: Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 1 obs hidden.

300956

Statistical Analysis of Preliminary Investigation Data
Table 14 - ANOVA Table for Log Lead (mg/kg) vs Log Cadmium (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGCD

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.96151	0.96151	15.751	0.0016
Error	13	0.79359	0.06105		
C Total	14	1.75511			

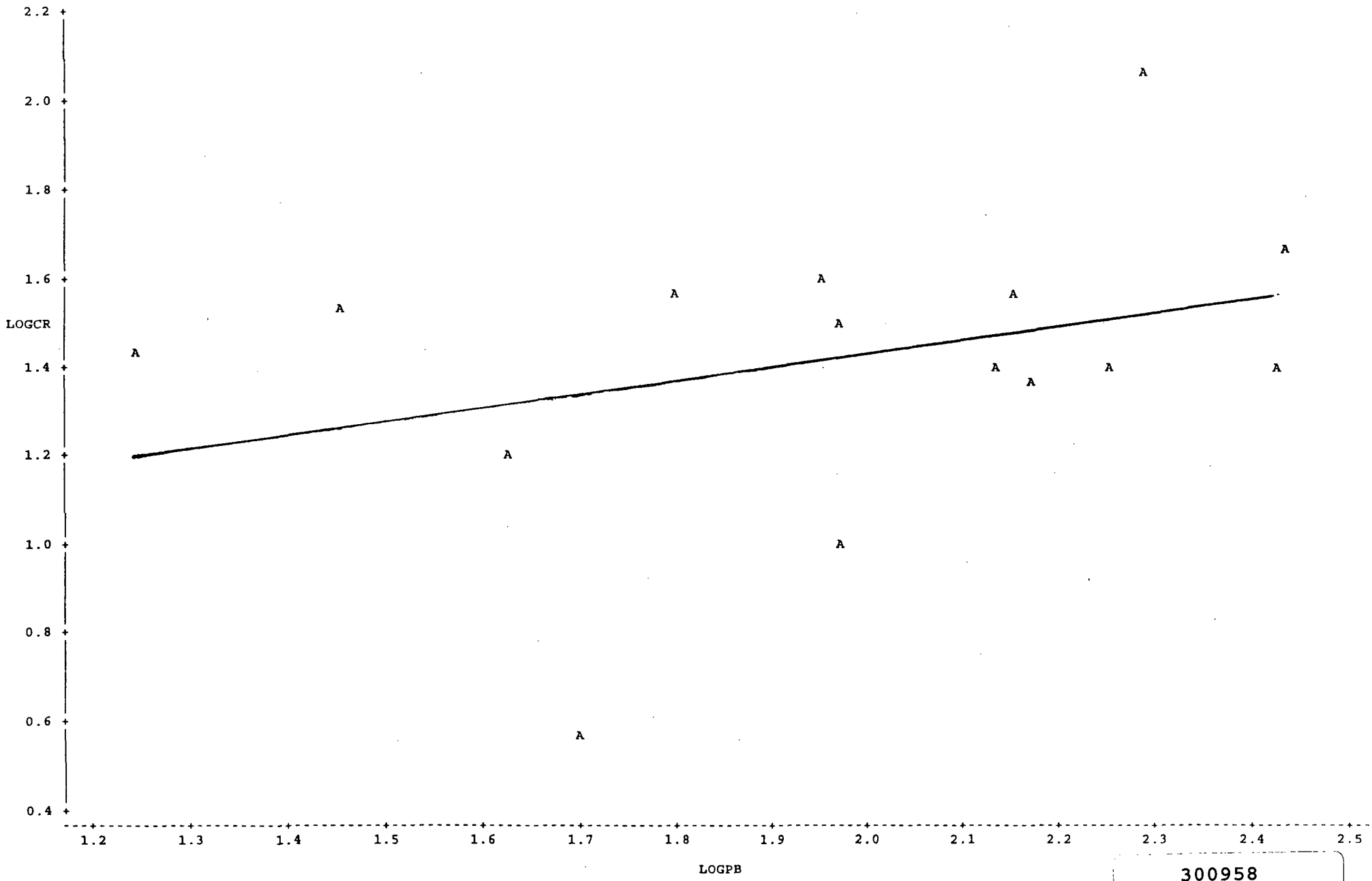
Root MSE	0.24707	R-square	0.5478
Dep Mean	-0.23286	Adj R-sq	0.5131
C.V.	-106.10309		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-1.710169	0.37766485	-4.528	0.0006
LOGPB	1	0.748418	0.18857928	3.969	0.0016

Figure 15 - Plot of Log Lead (mg/kg) vs Log Chromium (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGCR*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 1 obs hidden.

300958

BROS Phase S Work Plan
Statistical Analysis of inary Investigation Data
Table 15 - ANOVA Table for Log Lead (mg/kg) vs Log Chromium (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGCR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.16874	0.16874	1.605	0.2274
Error	13	1.36684	0.10514		
C Total	14	1.53558			

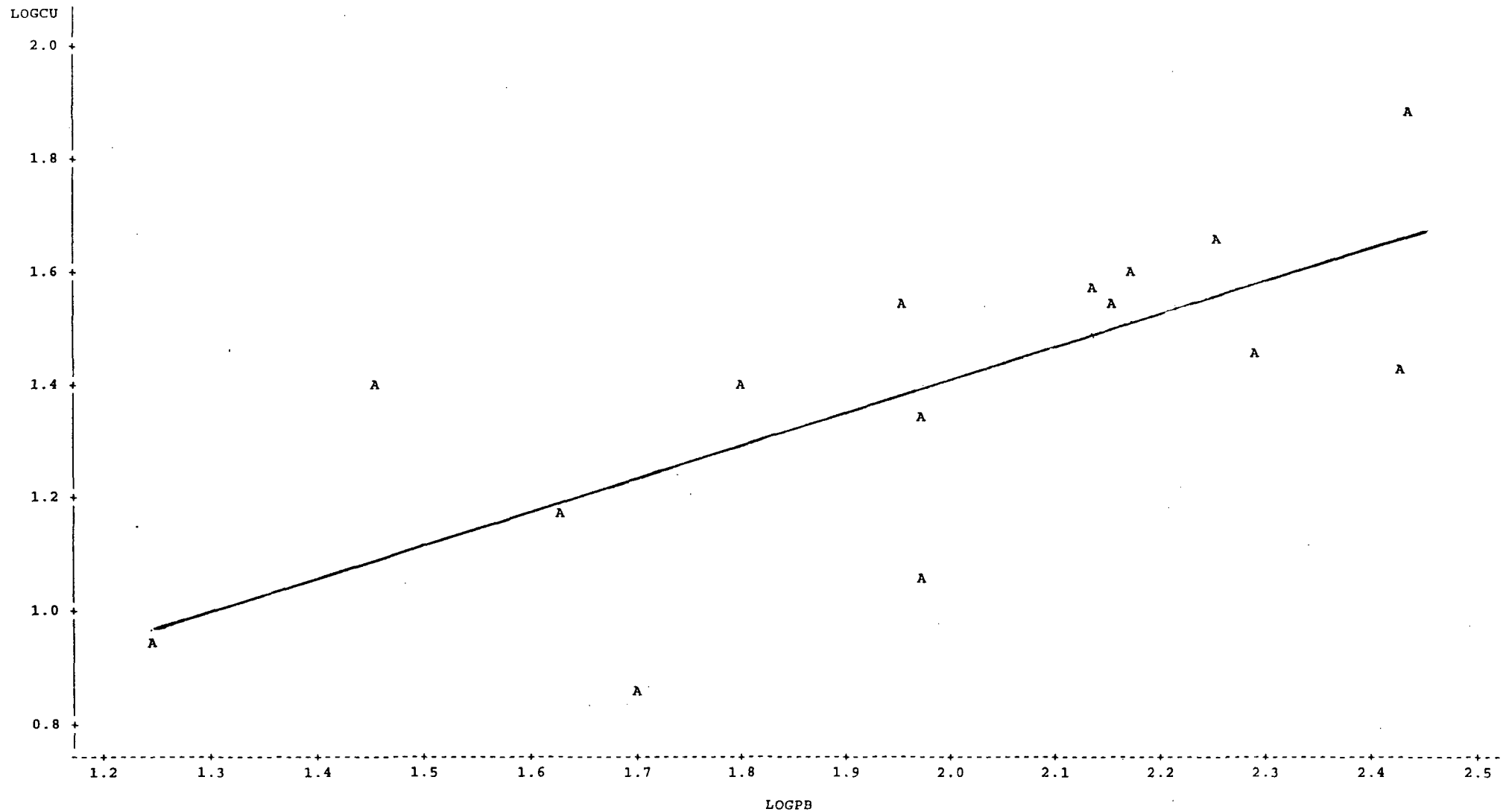
Root MSE	0.32426	R-square	0.1099
Dep Mean	1.41803	Adj R-sq	0.0414
C.V.	22.86657		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.799168	0.49564017	1.612	0.1309
LOGPB	1	0.313523	0.24748786	1.267	0.2274

Figure 16 - Plot of Log Lead (mg/kg) vs Log Copper (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGCU*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 1 obs hidden.

Table 16 - ANOVA Table for Log Lead (mg/kg) vs Log Copper (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGCU

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.57206	0.57206	13.369	0.0029
Error	13	0.55626	0.04279		
C Total	14	1.12832			

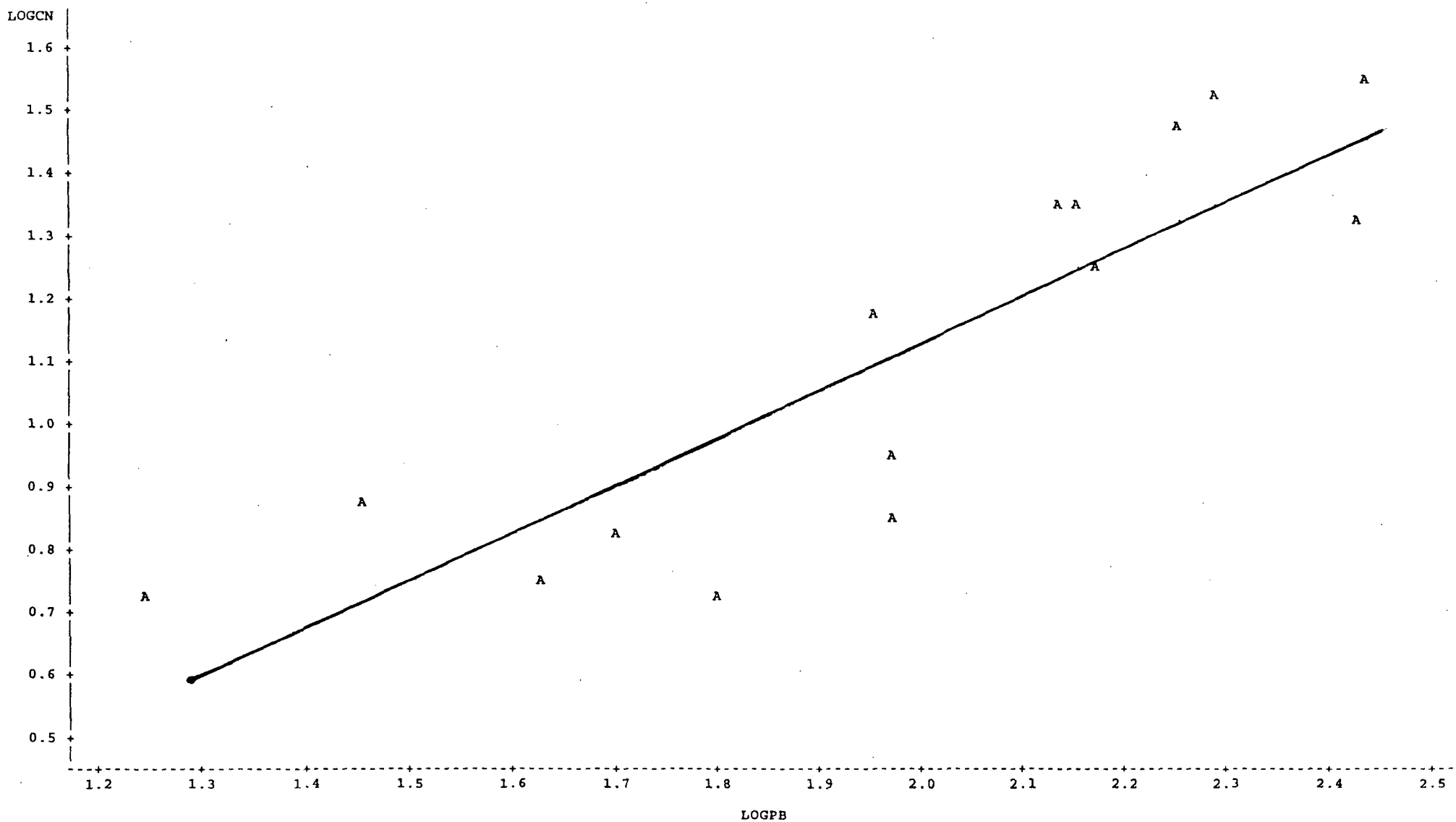
Root MSE	0.20686	R-square	0.5070
Dep Mean	1.39009	Adj R-sq	0.4691
C.V.	14.88075		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.250588	0.31618795	0.793	0.4423
LOGPB	1	0.577280	0.15788204	3.656	0.0029

Figure 17 - Plot of Log Lead (mg/kg) vs Log Cyanide (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGCN*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 2 obs hidden.

300962

Statistical Analysis of Preliminary Investigation Data
Table 17 - ANOVA Table for Log Lead (mg/kg) vs Log Cyanide (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGCN

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.98419	0.98419	38.529	0.0001
Error	13	0.33207	0.02554		
C Total	14	1.31626			

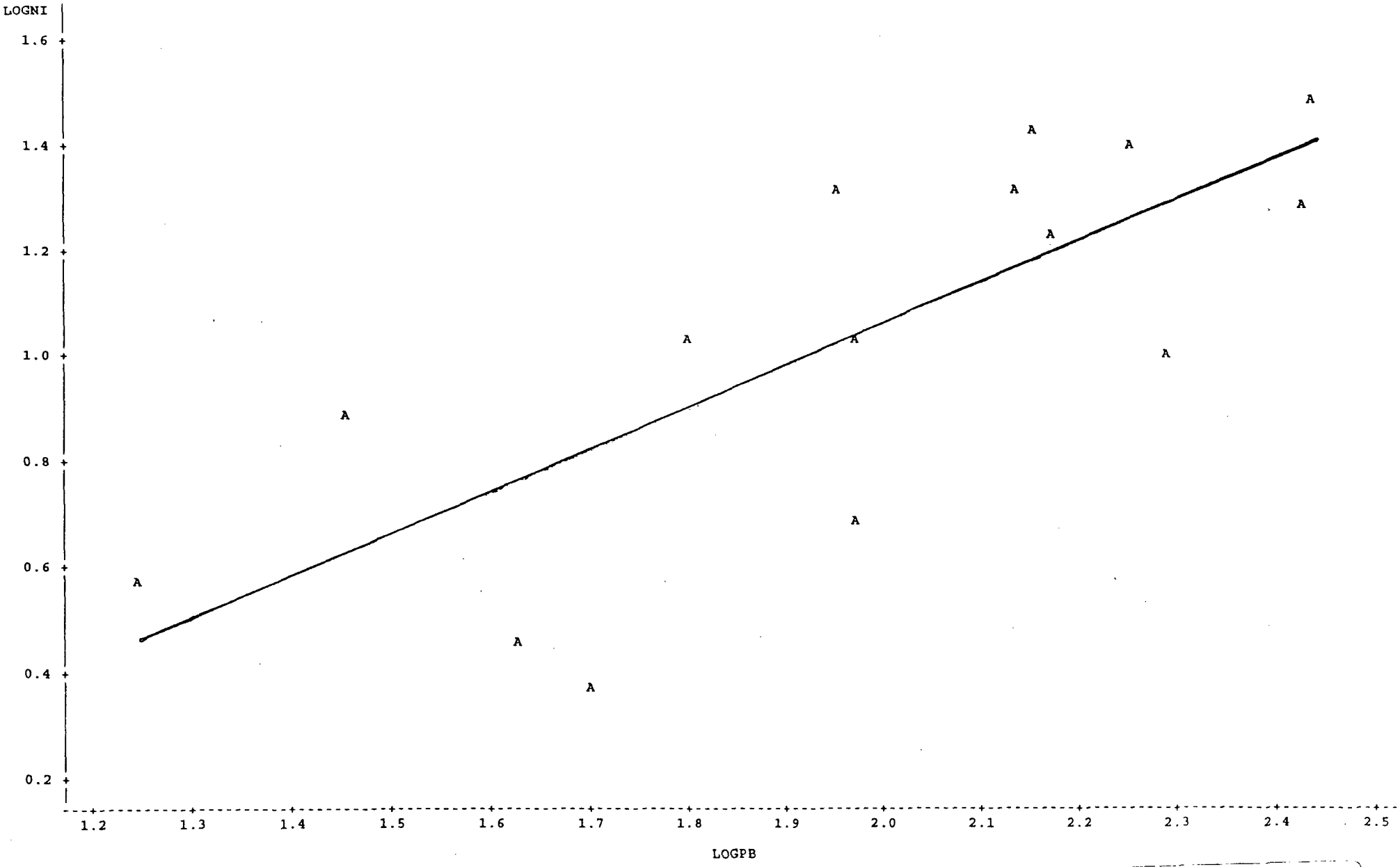
Root MSE	0.15983	R-square	0.7477
Dep Mean	1.11131	Adj R-sq	0.7283
C.V.	14.38170		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.383312	0.24430049	-1.569	0.1407
LOGPB	1	0.757190	0.12198649	6.207	0.0001

Figure 18 - Plot of Log Lead (mg/kg) vs Log Nickel (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGNI*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 2 obs hidden.

300964

Statistical Analysis of Preliminary Investigation Data
Table 18 - ANOVA Table for Log Lead (mg/kg) vs Log Nickel (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGNI

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.08083	1.08083	17.290	0.0011
Error	13	0.81265	0.06251		
C Total	14	1.89348			

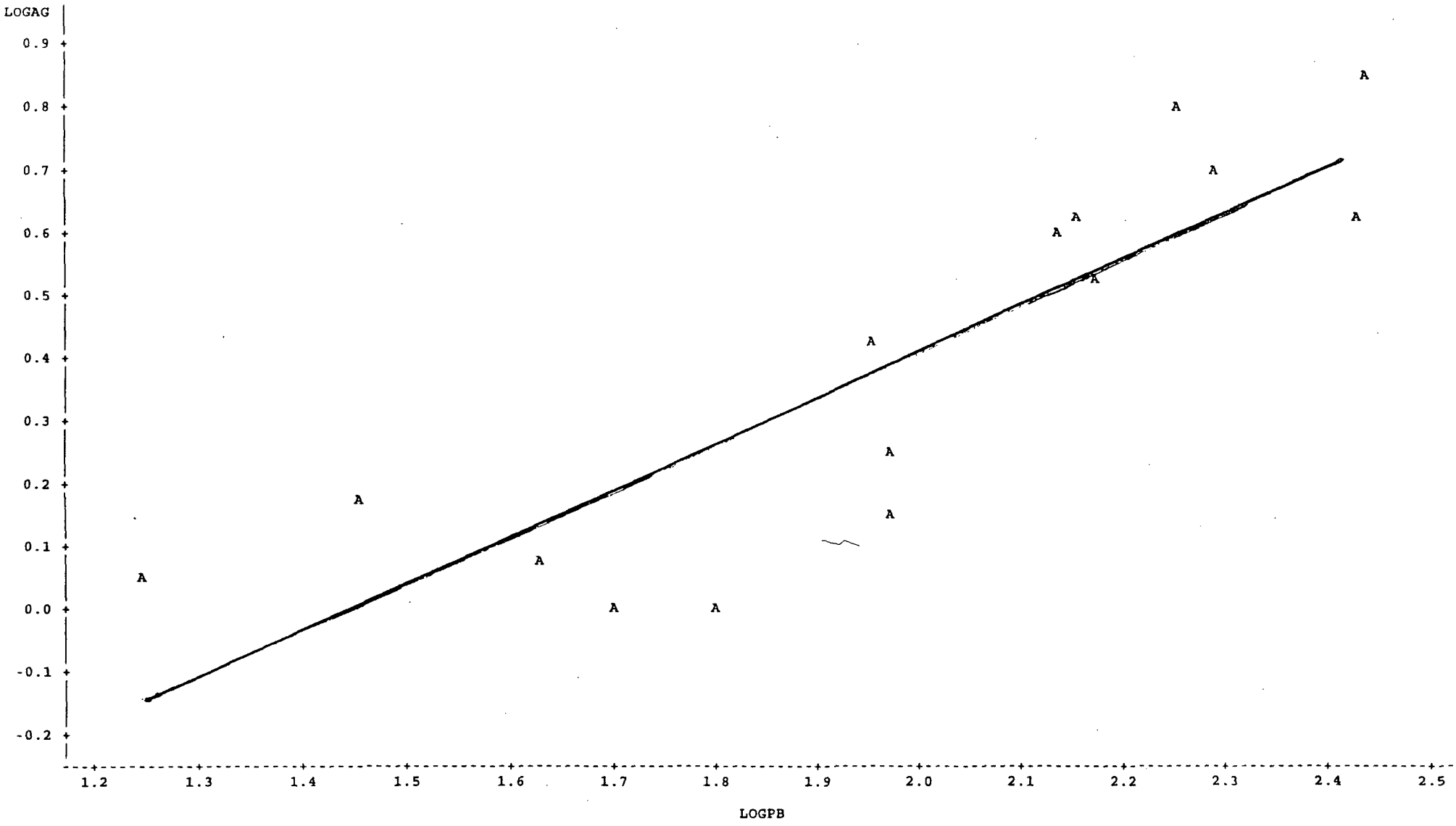
Root MSE	0.25002	R-square	0.5708
Dep Mean	1.03270	Adj R-sq	0.5378
C.V.	24.21064		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.533590	0.38217188	-1.396	0.1860
LOGPB	1	0.793497	0.19082977	4.158	0.0011

Statistical Analysis of Preliminary Investigation Data
Figure 19 - Plot of Log Lead (mg/kg) vs Log Silver (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGAG*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 2 obs hidden.

300966

Statistical Analysis of Preliminary Investigation Data
Table 19 - ANOVA Table for Log Lead (mg/kg) vs Log Silver (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGAG

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	0.94579	0.94579	36.053	0.0001
Error	13	0.34104	0.02623		
C Total	14	1.28683			

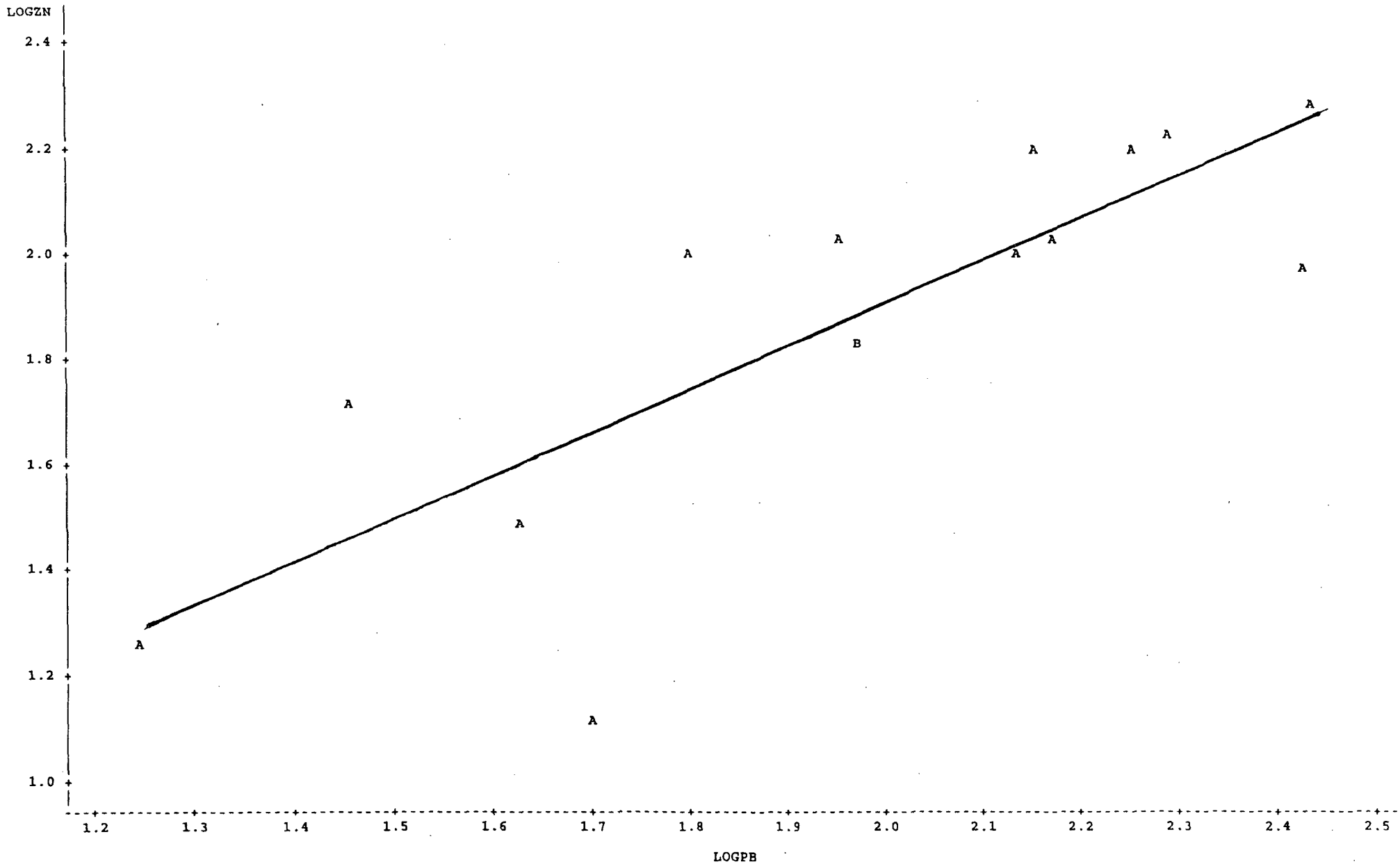
Root MSE	0.16197	R-square	0.7350
Dep Mean	0.38817	Adj R-sq	0.7146
C.V.	41.72641		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-1.077012	0.24757518	-4.350	0.0008
LOGPB	1	0.742273	0.12362164	6.004	0.0001

Figure 20 - Plot of Log Lead (mg/kg) vs Log Zinc (mg/kg)
Where Lead < 300 mg/kg

Plot of LOGZN*LOGPB. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 3 obs hidden.

300968

Statistical Analysis of Preliminary Investigation Data
Table 10 - ANOVA Table for Log Lead (mg/kg) vs Log Zinc (mg/kg)
Where Lead < 300 mg/kg

Model: MODEL1
Dependent Variable: LOGZN

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	1.16137	1.16137	25.471	0.0002
Error	13	0.59274	0.04560		
C Total	14	1.75411			

Root MSE	0.21353	R-square	0.6621
Dep Mean	1.87628	Adj R-sq	0.6361
C.V.	11.38053		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.252684	0.32639188	0.774	0.4527
LOGPB	1	0.822530	0.16297716	5.047	0.0002